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EXPANDABLE TUBULAR

Cross Reference To Related Applications

[001] This application is the U.S. National Stage application for PCT application serial no. PCT/US2004/028889, attorney docket no. 25791.307.02, filed on 9/7/2004, which claimed the benefit of the filing dates of: (1) U.S. provisional patent application serial no. 60/600679, attorney docket no 25791.194, filed on 8/11/2004, (2) U.S. provisional patent application serial no. 60/585370, attorney docket no 25791.299, filed on 7/2/2004, and (3) U.S. provisional patent application serial no. 60/500435, attorney docket no 25791.304, filed on 9/5/2003 , the disclosures of which are incorporated herein by reference.

[002] The application is a continuation-in-part of U.S. utility patent application serial no. 10/528498, attorney docket no. 25791.118.08, filed on 3/18/05, which was the National Stage for PCT application serial no. PCT/US03/025667, attorney docket no. 25791.118.02, filed on 8/18/03, which claimed the benefit of the filing date of U.S. provisional patent application serial no. 60/412653, attorney docket 25791.118, filed on 9/20/2002, the disclosures of which are incorporated herein by reference.

[003] This application is related to the following co-pending applications: (1) U.S. National State patent application serial no. _________, attorney docket no. 25791.304.10, filed on 3/2/2006; (2) U.S. National State patent application serial no. _________, attorney docket no. 25791.305.05, filed on ___________; (3) U.S. National State patent application serial no. _________, attorney docket no. 25791.306.04, filed on ___________; and (4) U.S. National State patent application serial no. _________, attorney docket no. 25791.308.07, filed on ___________, the disclosures of which are incorporated herein by reference.

[004] This application is related to the following co-pending applications: (1) U.S. Patent Number 6,497,289, which was filed as U.S. Patent Application serial no. 09/454,139, attorney docket no. 25791.03.02, filed on 12/3/1999, which claims priority from provisional application 60/111,293, filed on 12/7/98, (2) U.S. patent application serial no. 09/510,913, attorney docket no. 25791.7.02, filed on 2/23/2000, which claims priority from provisional application 60/121,702, filed on 2/25/99, (3) U.S. patent application serial no. 09/502,350, attorney docket no. 25791.8.02, filed on 2/10/2000, which claims priority from provisional application 60/119,611, filed on 2/11/99, (4) U.S. patent no. 6,328,113, which was filed as U.S. Patent Application serial number 09/440,338, attorney docket number 25791.9.02, filed on 11/15/99, which claims priority from provisional application 60/108,558, filed on 11/16/98, (5) U.S. patent application serial no. 10/169,434, attorney docket no. 25791.10.04, filed on 7/1/02, which claims priority from provisional application 60/183,546, filed on 2/18/00, (6) U.S. patent no. 6,640,903 which was filed as U.S. patent application serial no. 09/523,468, attorney docket no. 25791.11.02, filed on 3/10/2000, which claims priority from provisional

application 60/124,042, filed on 3/11/99, (7) U.S. patent number 6,568,471, which was filed as patent application serial no. 09/512,895, attorney docket no. 25791.12.02, filed on 2/24/2000, which claims priority from provisional application 60/121,841, filed on 2/26/99, (8) U.S. patent number 6,575,240, which was filed as patent application serial no. 09/511,941, attorney docket no. 25791.16.02, filed on 2/24/2000, which claims priority from provisional application 60/121,907, filed on 2/26/99, (9) U.S. patent number 6,557,640, which was filed as patent application serial no. 09/588,946, attorney docket no. 25791.17.02, filed on 6/7/2000, which claims priority from provisional application 60/137,998, filed on 6/7/99, (10) U.S. patent application serial no. 09/981,916, attorney docket no. 25791.18, filed on 10/18/01 as a continuation-in-part application of U.S. patent no. 6,328,113, which was filed as U.S. Patent Application serial number 09/440,338, attorney docket number 25791.9.02, filed on 11/15/99, which claims priority from provisional application 60/108,558, filed on 11/16/98, (11) U.S. patent number 6,604,763, which was filed as application serial no. 09/559,122, attorney docket no. 25791.23.02, filed on 4/26/2000, which claims priority from provisional application 60/131,106, filed on 4/26/99, (12) U.S. patent application serial no. 10/030,593, attorney docket no. 25791.25.08, filed on 1/8/02, which claims priority from provisional application 60/146,203, filed on 7/29/99, (13) U.S. provisional patent application serial no. 60/143,039, attorney docket no. 25791.26, filed on 7/9/99, (14) U.S. patent application serial no. 10/111,982, attorney docket no. 25791.27.08, filed on 4/30/02, which claims priority from provisional patent application serial no. 60/162,671, attorney docket no. 25791.27, filed on 11/1/1999, (15) U.S. provisional patent application serial no. 60/154,047, attorney docket no. 25791.29, filed on 9/16/1999, (16) U.S. provisional patent application serial no. 60/438,828, attorney docket no. 25791.31, filed on 1/9/03, (17) U.S. patent number 6,564,875, which was filed as application serial no. 09/679,907, attorney docket no. 25791.34.02, on 10/5/00, which claims priority from provisional patent application serial no. 60/159,082, attorney docket no. 25791.34, filed on 10/12/1999, (18) U.S. patent application serial no. 10/089,419, filed on 3/27/02, attorney docket no. 25791.36.03, which claims priority from provisional patent application serial no. 60/159,039, attorney docket no. 25791.36, filed on 10/12/1999, (19) U.S. patent application serial no. 09/679,906, filed on 10/5/00, attorney docket no. 25791.37.02, which claims priority from provisional patent application serial no. 60/159,033, attorney docket no. 25791.37, filed on 10/12/1999, (20) U.S. patent application serial no. 10/303,992, filed on 11/22/02, attorney docket no. 25791.38.07, which claims priority from provisional patent application serial no. 60/212,359, attorney docket no. 25791.38, filed on 6/19/2000, (21) U.S. provisional patent application serial no. 60/165,228, attorney docket no. 25791.39, filed on 11/12/1999, (22) U.S. provisional patent application serial no. 60/455,051, attorney docket no. 25791.40, filed on 3/14/03, (23) PCT application US02/2477, filed on 6/26/02, attorney docket no. 25791.44.02,

which claims priority from U.S. provisional patent application serial no. 60/303,711, attorney docket no. 25791.44, filed on 7/6/01, (24) U.S. patent application serial no. 10/311,412, filed on 12/12/02, attorney docket no. 25791.45.07, which claims priority from provisional patent application serial no. 60/221,443, attorney docket no. 25791.45, filed on 7/28/2000, (25) U.S. patent application serial no. 10/, filed on 12/18/02, attorney docket no. 25791.46.07, which claims priority from provisional patent application serial no. 60/221,645, attorney docket no. 25791.46, filed on 7/28/2000, (26) U.S. patent application serial no. 10/322,947, filed on 1/22/03, attorney docket no. 25791.47.03, which claims priority from provisional patent application serial no. 60/233,638, attorney docket no. 25791.47, filed on 9/18/2000, (27) U.S. patent application serial no. 10/406,648, filed on 3/31/03, attorney docket no. 25791.48.06, which claims priority from provisional patent application serial no. 60/237,334, attorney docket no. 25791.48, filed on 10/2/2000, (28) PCT application US02/04353, filed on 2/14/02, attorney docket no. 25791.50.02, which claims priority from U.S. provisional patent application serial no. 60/270,007, attorney docket no. 25791.50, filed on 2/20/2001, (29) U.S. patent application serial no. 10/465,835, filed on 6/13/03, attorney docket no. 25791.51.06, which claims priority from provisional patent application serial no. 60/262,434, attorney docket no. 25791.51, filed on 1/17/2001, (30) U.S. patent application serial no. 10/465,831, filed on 6/13/03, attorney docket no. 25791.52.06, which claims priority from U.S. provisional patent application serial no. 60/259,486, attorney docket no. 25791.52, filed on 1/3/2001, (31) U.S. provisional patent application serial no. 60/452,303, filed on 3/5/03, attorney docket no. 25791.53, (32) U.S. patent number 6,470,966, which was filed as patent application serial number 09/850,093, filed on 5/7/01, attorney docket no. 25791.55, as a divisional application of U.S. Patent Number 6,497,289, which was filed as U.S. Patent Application serial no. 09/454,139, attorney docket no. 25791.03.02, filed on 12/3/1999, which claims priority from provisional application 60/111,293, filed on 12/7/98, (33) U.S. patent number 6,561,227, which was filed as patent application serial number 09/852,026 , filed on 5/9/01, attorney docket no. 25791.56, as a divisional application of U.S. Patent Number 6,497,289, which was filed as U.S. Patent Application serial no. 09/454,139, attorney docket no. 25791.03.02, filed on 12/3/1999, which claims priority from provisional application 60/111,293, filed on 12/7/98, (34) U.S. patent application serial number 09/852,027, filed on 5/9/01, attorney docket no. 25791.57, as a divisional application of U.S. Patent Number 6,497,289, which was filed as U.S. Patent Application serial no. 09/454,139, attorney docket no. 25791.03.02, filed on 12/3/1999, which claims priority from provisional application 60/111,293, filed on 12/7/98, (35) PCT Application US02/25608, attorney docket no. 25791.58.02, filed on 8/13/02, which claims priority from provisional application 60/318,021, filed on 9/7/01, attorney docket no. 25791.58, (36) PCT Application US02/24399, attorney docket no. 25791.59.02, filed on 8/1/02, which claims priority from U.S. provisional patent

application serial no. 60/313,453, attorney docket no. 25791.59, filed on 8/20/2001, (37) PCT Application US02/29856, attorney docket no. 25791.60.02, filed on 9/19/02, which claims priority from U.S. provisional patent application serial no. 60/326,886, attorney docket no. 25791.60, filed on 10/3/2001, (38) PCT Application US02/20256, attorney docket no. 25791.61.02, filed on 6/26/02, which claims priority from U.S. provisional patent application serial no. 60/303,740, attorney docket no. 25791.61, filed on 7/6/2001, (39) U.S. patent application serial no. 09/962,469, filed on 9/25/01, attorney docket no. 25791.62, which is a divisional of U.S. patent application serial no. 09/523,468, attorney docket no. 25791.11.02, filed on 3/10/2000, (now U.S. Patent 6,640,903 which issued 11/4/2003), which claims priority from provisional application 60/124,042, filed on 3/11/99, (40) U.S. patent application serial no. 09/962,470, filed on 9/25/01, attorney docket no. 25791.63, which is a divisional of U.S. patent application serial no. 09/523,468, attorney docket no. 25791.11.02, filed on 3/10/2000, (now U.S. Patent 6,640,903 which issued 11/4/2003), which claims priority from provisional application 60/124,042, filed on 3/11/99, (41) U.S. patent application serial no. 09/962,471, filed on 9/25/01, attorney docket no. 25791.64, which is a divisional of U.S. patent application serial no. 09/523,468, attorney docket no. 25791.11.02, filed on 3/10/2000, (now U.S. Patent 6,640,903 which issued 11/4/2003), which claims priority from provisional application 60/124,042, filed on 3/11/99, (42) U.S. patent application serial no. 09/962,467, filed on 9/25/01, attorney docket no. 25791.65, which is a divisional of U.S. patent application serial no. 09/523,468, attorney docket no. 25791.11.02, filed on 3/10/2000, (now U.S. Patent 6,640,903 which issued 11/4/2003), which claims priority from provisional application 60/124,042, filed on 3/11/99, (43) U.S. patent application serial no. 09/962,468, filed on 9/25/01, attorney docket no. 25791.66, which is a divisional of U.S. patent application serial no. 09/523,468, attorney docket no. 25791.11.02, filed on 3/10/2000, (now U.S. Patent 6,640,903 which issued 11/4/2003), which claims priority from provisional application 60/124,042, filed on 3/11/99, (44) PCT application US 02/25727, filed on 8/14/02, attorney docket no. 25791.67.03, which claims priority from U.S. provisional patent application serial no. 60/317,985, attorney docket no. 25791.67, filed on 9/6/2001, and U.S. provisional patent application serial no. 60/318,386, attorney docket no. 25791.67.02, filed on 9/10/2001, (45) PCT application US 02/39425, filed on 12/10/02, attorney docket no. 25791.68.02, which claims priority from U.S. provisional patent application serial no. 60/343,674 , attorney docket no. 25791.68, filed on 12/27/2001, (46) U.S. utility patent application serial no. 09/969,922, attorney docket no. 25791.69, filed on 10/3/2001, (now U.S. Patent 6,634,431 which issued 10/21/2003), which is a continuation-in-part application of U.S. patent no. 6,328,113, which was filed as U.S. Patent Application serial number 09/440,338, attorney docket number 25791.9.02, filed on 11/15/99, which claims priority from provisional application 60/108,558, filed on 11/16/98, (47) U.S. utility

patent application serial no. 10/516,467, attorney docket no. 25791.70, filed on 12/10/01, which is a continuation application of U.S. utility patent application serial no. 09/969,922, attorney docket no. 25791.69, filed on 10/3/2001, (now U.S. Patent 6,634,431 which issued 10/21/2003), which is a continuation-in-part application of U.S. patent no. 6,328,113, which was filed as U.S. Patent Application serial number 09/440,338, attorney docket number 25791.9.02, filed on 11/15/99, which claims priority from provisional application 60/108,558, filed on 11/16/98, (48) PCT application US 03/00609, filed on 1/9/03, attorney docket no. 25791.71.02, which claims priority from U.S. provisional patent application serial no. 60/357,372 , attorney docket no. 25791.71, filed on 2/15/02, (49) U.S. patent application serial no. 10/074,703, attorney docket no. 25791.74, filed on 2/12/02, which is a divisional of U.S. patent number 6,568,471, which was filed as patent application serial no. 09/512,895, attorney docket no. 25791.12.02, filed on 2/24/2000, which claims priority from provisional application 60/121,841, filed on 2/26/99, (50) U.S. patent application serial no. 10/074,244, attorney docket no. 25791.75, filed on 2/12/02, which is a divisional of U.S. patent number 6,568,471, which was filed as patent application serial no. 09/512,895, attorney docket no. 25791.12.02, filed on 2/24/2000, which claims priority from provisional application 60/121,841, filed on 2/26/99, (51) U.S. patent application serial no. 10/076,660, attorney docket no. 25791.76, filed on 2/15/02, which is a divisional of U.S. patent number 6,568,471, which was filed as patent application serial no. 09/512,895, attorney docket no. 25791.12.02, filed on 2/24/2000, which claims priority from provisional application 60/121,841, filed on 2/26/99, (52) U.S. patent application serial no. 10/076,661, attorney docket no. 25791.77, filed on 2/15/02, which is a divisional of U.S. patent number 6,568,471, which was filed as patent application serial no. 09/512,895, attorney docket no. 25791.12.02, filed on 2/24/2000, which claims priority from provisional application 60/121,841, filed on 2/26/99, (53) U.S. patent application serial no. 10/076,659, attorney docket no. 25791.78, filed on 2/15/02, which is a divisional of U.S. patent number 6,568,471, which was filed as patent application serial no. 09/512,895, attorney docket no. 25791.12.02, filed on 2/24/2000, which claims priority from provisional application 60/121,841, filed on 2/26/99, (54) U.S. patent application serial no. 10/078,928, attorney docket no. 25791.79, filed on 2/20/02, which is a divisional of U.S. patent number 6,568,471, which was filed as patent application serial no. 09/512,895, attorney docket no. 25791.12.02, filed on 2/24/2000, which claims priority from provisional application 60/121,841, filed on 2/26/99, (55) U.S. patent application serial no. 10/078,922, attorney docket no. 25791.80, filed on 2/20/02, which is a divisional of U.S. patent number 6,568,471, which was filed as patent application serial no. 09/512,895, attorney docket no. 25791.12.02, filed on 2/24/2000, which claims priority from provisional application 60/121,841, filed on 2/26/99, (56) U.S. patent application serial no. 10/078,921, attorney

docket no. 25791.81, filed on 2/20/02, which is a divisional of U.S. patent number 6,568,471, which was filed as patent application serial no. 09/512,895, attorney docket no. 25791.12.02, filed on 2/24/2000, which claims priority from provisional application 60/121,841, filed on 2/26/99, (57) U.S. patent application serial no. 10/261,928, attorney docket no. 25791.82, filed on 10/1/02, which is a divisional of U.S. patent number 6,557,640, which was filed as patent application serial no. 09/588,946, attorney docket no. 25791.17.02, filed on 6/7/2000, which claims priority from provisional application 60/137,998, filed on 6/7/99, (58) U.S. patent application serial no. 10/079,276, attorney docket no. 25791.83, filed on 2/20/02, which is a divisional of U.S. patent number 6,568,471, which was filed as patent application serial no. 09/512,895, attorney docket no. 25791.12.02, filed on 2/24/2000, which claims priority from provisional application 60/121,841, filed on 2/26/99, (59) U.S. patent application serial no. 10/262,009, attorney docket no. 25791.84, filed on 10/1/02, which is a divisional of U.S. patent number 6,557,640, which was filed as patent application serial no. 09/588,946, attorney docket no. 25791.17.02, filed on 6/7/2000, which claims priority from provisional application 60/137,998, filed on 6/7/99, (60) U.S. patent application serial no. 10/092,481, attorney docket no. 25791.85, filed on 3/7/02, which is a divisional of U.S. patent number 6,568,471, which was filed as patent application serial no. 09/512,895, attorney docket no. 25791.12.02, filed on 2/24/2000, which claims priority from provisional application 60/121,841, filed on 2/26/99, (61) U.S. patent application serial no. 10/261,926, attorney docket no. 25791.86, filed on 10/1/02, which is a divisional of U.S. patent number 6,557,640, which was filed as patent application serial no. 09/588,946, attorney docket no. 25791.17.02, filed on 6/7/2000, which claims priority from provisional application 60/137,998, filed on 6/7/99, (62) PCT application US 02/36157, filed on 11/12/02, attorney docket no. 25791.87.02, which claims priority from U.S. provisional patent application serial no. 60/338,996, attorney docket no. 25791.87, filed on 11/12/01, (63) PCT application US 02/36267, filed on 11/12/02, attorney docket no. 25791.88.02, which claims priority from U.S. provisional patent application serial no. 60/339,013, attorney docket no. 25791.88, filed on 11/12/01, (64) PCT application US 03/11765, filed on 4/16/03, attorney docket no. 25791.89.02, which claims priority from U.S. provisional patent application serial no. 60/383,917, attorney docket no. 25791.89, filed on 5/29/02, (65) PCT application US 03/15020, filed on 5/12/03, attorney docket no. 25791.90.02, which claims priority from U.S. provisional patent application serial no. 60/391,703, attorney docket no. 25791.90, filed on 6/26/02, (66) PCT application US 02/39418, filed on 12/10/02, attorney docket no. 25791.92.02, which claims priority from U.S. provisional patent application serial no. 60/346,309, attorney docket no. 25791.92, filed on 1/7/02, (67) PCT application US 03/06544, filed on 3/4/03, attorney docket no. 25791.93.02, which claims priority from U.S. provisional patent application serial no. 60/372,048, attorney docket no. 25791.93, filed on

4/12/02, (68) U.S. patent application serial no. 10/331,718, attorney docket no. 25791.94, filed on 12/30/02, which is a divisional U.S. patent application serial no. 09/679,906, filed on 10/5/00, attorney docket no. 25791.37.02, which claims priority from provisional patent application serial no. 60/159,033, attorney docket no. 25791.37, filed on 10/12/1999, (69) PCT application US 03/04837, filed on 2/29/03, attorney docket no. 25791.95.02, which claims priority from U.S. provisional patent application serial no. 60/363,829, attorney docket no. 25791.95, filed on 3/13/02, (70) U.S. patent application serial no. 10/261,927, attorney docket no. 25791.97, filed on 10/1/02, which is a divisional of U.S. patent number 6,557,640, which was filed as patent application serial no. 09/588,946, attorney docket no. 25791.17.02, filed on 6/7/2000, which claims priority from provisional application 60/137,998, filed on 6/7/99, (71) U.S. patent application serial no. 10/262,008, attorney docket no. 25791.98, filed on 10/1/02, which is a divisional of U.S. patent number 6,557,640, which was filed as patent application serial no. 09/588,946, attorney docket no. 25791.17.02, filed on 6/7/2000, which claims priority from provisional application 60/137,998, filed on 6/7/99, (72) U.S. patent application serial no. 10/261,925, attorney docket no. 25791.99, filed on 10/1/02, which is a divisional of U.S. patent number 6,557,640, which was filed as patent application serial no. 09/588,946, attorney docket no. 25791.17.02, filed on 6/7/2000, which claims priority from provisional application 60/137,998, filed on 6/7/99, (73) U.S. patent application serial no. 10/199,524, attorney docket no. 25791.100, filed on 7/19/02, which is a continuation of U.S. Patent Number 6,497,289, which was filed as U.S. Patent Application serial no. 09/454,139, attorney docket no. 25791.03.02, filed on 12/3/1999, which claims priority from provisional application 60/111,293, filed on 12/7/98, (74) PCT application US 03/10144, filed on 3/28/03, attorney docket no. 25791.101.02, which claims priority from U.S. provisional patent application serial no. 60/372,632, attorney docket no. 25791.101, filed on 4/15/02, (75) U.S. provisional patent application serial no. 60/412,542, attorney docket no. 25791.102, filed on 9/20/02, (76) PCT application US 03/14153, filed on 5/6/03, attorney docket no. 25791.104.02, which claims priority from U.S. provisional patent application serial no. 60/380,147, attorney docket no. 25791.104, filed on 5/6/02, (77) PCT application US 03/19993, filed on 6/24/03, attorney docket no. 25791.106.02, which claims priority from U.S. provisional patent application serial no. 60/397,284, attorney docket no. 25791.106, filed on 7/19/02, (78) PCT application US 03/13787, filed on 5/5/03, attorney docket no. 25791.107.02, which claims priority from U.S. provisional patent application serial no. 60/387,486, attorney docket no. 25791.107, filed on 6/10/02, (79) PCT application US 03/18530, filed on 6/11/03, attorney docket no. 25791.108.02, which claims priority from U.S. provisional patent application serial no. 60/387,961, attorney docket no. 25791.108, filed on 6/12/02, (80) PCT application US 03/20694, filed on 7/1/03, attorney docket no. 25791.110.02, which claims priority from U.S. provisional patent application serial no.

60/398,061, attorney docket no. 25791.110, filed on 7/24/02, (81) PCT application US 03/20870, filed on 7/2/03, attorney docket no. 25791.111.02, which claims priority from U.S. provisional patent application serial no. 60/399,240, attorney docket no. 25791.111, filed on 7/29/02, (82) U.S. provisional patent application serial no. 60/412,487, attorney docket no. 25791.112, filed on 9/20/02, (83) U.S. provisional patent application serial no. 60/412,488, attorney docket no. 25791.114, filed on 9/20/02, (84) U.S. patent application serial no. 10/280,356, attorney docket no. 25791.115, filed on 10/25/02, which is a continuation of U.S. patent number 6,470,966, which was filed as patent application serial number 09/850,093, filed on 5/7/01, attorney docket no. 25791.55, as a divisional application of U.S. Patent Number 6,497,289, which was filed as U.S. Patent Application serial no. 09/454,139, attorney docket no. 25791.03.02, filed on 12/3/1999, which claims priority from provisional application 60/111,293, filed on 12/7/98, (85) U.S. provisional patent application serial no. 60/412,177, attorney docket no. 25791.117, filed on 9/20/02, (86) U.S. provisional patent application serial no. 60/412,653, attorney docket no. 25791.118, filed on 9/20/02, (87) U.S. provisional patent application serial no. 60/405,610, attorney docket no. 25791.119, filed on 8/23/02, (88) U.S. provisional patent application serial no. 60/405,394, attorney docket no. 25791.120, filed on 8/23/02, (89) U.S. provisional patent application serial no. 60/412,544, attorney docket no. 25791.121, filed on 9/20/02, (90) PCT application US 03/24779, filed on 8/8/03, attorney docket no. 25791.125.02, which claims priority from U.S. provisional patent application serial no. 60/407,442, attorney docket no. 25791.125, filed on 8/30/02, (91) U.S. provisional patent application serial no. 60/423,363, attorney docket no. 25791.126, filed on 12/10/02, (92) U.S. provisional patent application serial no. 60/412,196, attorney docket no. 25791.127, filed on 9/20/02, (93) U.S. provisional patent application serial no. 60/412,187, attorney docket no. 25791.128, filed on 9/20/02, (94) U.S. provisional patent application serial no. 60/412,371, attorney docket no. 25791.129, filed on 9/20/02, (95) U.S. patent application serial no. 10/382,325, attorney docket no. 25791.145, filed on 3/5/03, which is a continuation of U.S. patent number 6,557,640, which was filed as patent application serial no. 09/588,946, attorney docket no. 25791.17.02, filed on 6/7/2000, which claims priority from provisional application 60/137,998, filed on 6/7/99, (96) U.S. patent application serial no. 10/624,842, attorney docket no. 25791.151, filed on 7/22/03, which is a divisional of U.S. patent application serial no. 09/502,350, attorney docket no. 25791.8.02, filed on 2/10/2000, which claims priority from provisional application 60/119,611, filed on 2/11/99, (97) U.S. provisional patent application serial no. 60/431,184, attorney docket no. 25791.157, filed on 12/5/02, (98) U.S. provisional patent application serial no. 60/448,526, attorney docket no. 25791.185, filed on 2/18/03, (99) U.S. provisional patent application serial no. 60/461,539, attorney docket no. 25791.186, filed on 4/9/03, (100) U.S. provisional patent application serial no. 60/462,750, attorney docket no. 25791.193, filed on 4/14/03,

(101) U.S. provisional patent application serial no. 60/436,106, attorney docket no. 25791.200, filed on 12/23/02, (102) U.S. provisional patent application serial no. 60/442,942, attorney docket no. 25791.213, filed on 1/27/03, (103) U.S. provisional patent application serial no. 60/442,938, attorney docket no. 25791.225, filed on 1/27/03, (104) U.S. provisional patent application serial no. 60/418,687, attorney docket no. 25791.228, filed on 4/18/03, (105) U.S. provisional patent application serial no. 60/454,896, attorney docket no. 25791.236, filed on 3/14/03, (106) U.S. provisional patent application serial no. 60/450,504, attorney docket no. 25791.238, filed on 2/26/03, (107) U.S. provisional patent application serial no. 60/451,152, attorney docket no. 25791.239, filed on 3/9/03, (108) U.S. provisional patent application serial no. 60/455,124, attorney docket no. 25791.241, filed on 3/17/03, (109) U.S. provisional patent application serial no. 60/453,678, attorney docket no. 25791.253, filed on 3/11/03, (110) U.S. patent application serial no. 10/421,682, attorney docket no. 25791.256, filed on 4/23/03, which is a continuation of U.S. patent application serial no. 09/523,468, attorney docket no. 25791.11.02, filed on 3/10/2000, (now U.S. Patent 6,640,903 which issued 11/4/2003), which claims priority from provisional application 60/124,042, filed on 3/11/99, (111) U.S. provisional patent application serial no. 60/457,965, attorney docket no. 25791.260, filed on 3/27/03, (112) U.S. provisional patent application serial no. 60/455,718, attorney docket no. 25791.262, filed on 3/18/03, (113) U.S. patent number 6,550,821, which was filed as patent application serial no. 09/811,734, filed on 3/19/01, (114) U.S. patent application serial no. 10/436,467, attorney docket no. 25791.268, filed on 5/12/03, which is a continuation of U.S. patent number 6,604,763, which was filed as application serial no. 09/559,122, attorney docket no. 25791.23.02, filed on 4/26/2000, which claims priority from provisional application 60/131,106, filed on 4/26/99, (115) U.S. provisional patent application serial no. 60/459,776, attorney docket no. 25791.270, filed on 4/2/03, (116) U.S. provisional patent application serial no. 60/461,094, attorney docket no. 25791.272, filed on 4/8/03, (117) U.S. provisional patent application serial no. 60/461,038, attorney docket no. 25791.273, filed on 4/7/03, (118) U.S. provisional patent application serial no. 60/463,586, attorney docket no. 25791.277, filed on 4/17/03, (119) U.S. provisional patent application serial no. 60/472,240, attorney docket no. 25791.286, filed on 5/20/03, (120) U.S. patent application serial no. 10/619,285, attorney docket no. 25791.292, filed on 7/14/03, which is a continuation-in-part of U.S. utility patent application serial no. 09/969,922, attorney docket no. 25791.69, filed on 10/3/2001, (now U.S. Patent 6,634,431 which issued 10/21/2003), which is a continuation-in-part application of U.S. patent no. 6,328,113, which was filed as U.S. Patent Application serial number 09/440,338, attorney docket number 25791.9.02, filed on 11/15/99, which claims priority from provisional application 60/108,558, filed on 11/16/98, (121) U.S. utility patent application serial no. 10/418,688, attorney docket no. 25791.257, which was filed on 4/18/03, as a division of U.S. utility patent application

serial no. 09/523,468, attorney docket no. 25791.11.02, filed on 3/10/2000, (now U.S. Patent 6,640,903 which issued 11/4/2003), which claims priority from provisional application 60/124,042, filed on 3/11/99; (122) PCT patent application serial no. PCT/US2004/06246, attor ney docket no. 25791.238.02, filed on 2/26/2004; (123) PCT patent application serial number PCT/US2004/08170, attorney docket number 25791.40.02, filed on 3/15/04; (124) PCT patent application serial number PCT/US2004/08171, attorney docket number 25791.236.02, filed on 3/15/04; (125) PCT patent application serial number PCT/US2004/08073, attorney docket number 25791.262.02, filed on 3/18/04; (126) PCT patent application serial number PCT/US2004/07711, attorney docket number 25791.253.02, filed on 3/11/2004; (127) PCT patent application serial number PCT/US2004/029025, attorney docket number 25791.260.02, filed on 3/26/2004; (128) PCT patent application serial number PCT/US2004/010317, attorney docket number 25791.270.02, filed on 4/2/2004; (129) PCT patent application serial number PCT/US2004/010712, attorney docket number 25791.272.02, filed on 4/6/2004; (130) PCT patent application serial number PCT/US2004/010762, attorney docket number 25791.273.02, filed on 4/6/2004; (131) PCT patent application serial number PCT/US2004/011973, attorney docket number 25791.277.02, filed on 4/15/2004; (132) U.S. provisional patent application serial number 60/495056, attorney docket number 25791.301, filed on 8/14/2003; (133) U.S. provisional patent application serial number 60/600679, attorney docket number 25791.194, filed on 8/11/2004; (134) PCT patent application serial number PCT/US2005/027318, attorney docket number 25791.329.02, filed on 7/29/2005; (135) PCT patent application serial number PCT/US2005/028936, attorney docket number 25791.338.02, filed on 8/12/2005; (136) PCT patent application serial number PCT/US2005/028669, attorney docket number 25791.194.02, filed on 8/11/2005; (137) PCT patent application serial number PCT/US2005/028453, attorney docket number 25791.371, filed on 8/11/2005; (138) PCT patent application serial number PCT/US2005/028641, attorney docket number 25791.372, filed on 8/11/2005; (139) PCT patent application serial number PCT/US2005/028819, attorney docket number 25791.373, filed on 8/11/2005; (140) PCT patent application serial number PCT/US2005/028446, attorney docket number 25791.374, filed on 8/11/2005; (141) PCT patent application serial number PCT/US2005/028642, attorney docket number 25791.375, filed on 8/11/2005; (142) PCT patent application serial number PCT/US2005/028451, attorney docket number 25791.376, filed on 8/11/2005, and (143). PCT patent application serial number PCT/US2005/028473, attorney docket number 25791.377, filed on 8/11/2005, (144) U.S. utility patent application serial number 10/546082, attorney docket number 25791.378, filed on 8/16/2005, (145) U.S. utility patent application serial number 10/546076, attorney docket number 25791.379, filed on 8/16/2005, (146) U.S. utility patent application serial number 10/545936, attorney docket

number 25791.380, filed on 8/16/2005, (147) U.S. utility patent application serial number 10/546079, attorney docket number 25791.381, filed on 8/16/2005 (148) U.S. utility patent application serial number 10/545941, attorney docket number 25791.382, filed on 8/16/2005, (149) U.S. utility patent application serial number 546078, attorney docket number 25791.383, filed on 8/16/2005, filed on 8/11/2005., (150) U.S. utility patent application serial number 10/545941, attorney docket number 25791.185.05, filed on 8/16/2005, (151) U.S. utility patent application serial number 11/249967, attorney docket number 25791.384, filed on 10/13//2005, (152) U.S. provisional patent application serial number 60/734302, attorney docket number 25791.24, filed on 11/7/2005, (153) U.S. provisional patent application serial number 60/725181, attorney docket number 25791.184, filed on 10/11/2005, (154) PCT patent application serial number PCT/US2005/023391, attorney docket number 25791.299.02 filed 6/29/2005 which claims priority from U.S. provisional patent application serial number 60/585370, attorney docket number 25791.299, filed on 7/2/2004, (155) U.S. provisional patent application serial number 60/721579, attorney docket number 25791.327, filed on 9/28/2005, (156) U.S. provisional patent application serial number 60/717391, attorney docket number 25791.214, filed on 9/15/2005, (157) U.S. provisional patent application serial number 60/702935, attorney docket number 25791.133, filed on 7/27/2005, (158) U.S. provisional patent application serial number 60/663913, attorney docket number 25791.32, filed on 3/21/2005, (159) U.S. provisional patent application serial number 60/652564, attorney docket number 25791.348, filed on 2/14/2005, (160) U.S. provisional patent application serial number 60/645840, attorney docket number 25791.324, filed on 1/21/2005, (161) PCT patent application serial number PCT/US2005/__________, attorney docket number 25791.326.02, filed on 11/29/2005 which claims priority from U.S. provisional patent application serial number 60/631703, attorney docket number 25791.326, filed on 11/30/2004, (162) U.S. provisional patent application serial number ____________, attorney docket number 25791.339, filed on 12/22/2005, (163) U.S. National Stage application serial no. 10/548934, attorney docket no. 25791.253.05, filed on 9/12/2005; (164) U.S. National Stage application serial no. 10/549410, attorney docket no. 25791.262.05, filed on 9/13/2005; (165) U.S. Provisional Patent Application No. 60/717391, attorney docket no. 25791.214 filed on 9/15/2005; (166) U.S. National Stage application serial no. 10/550906, attorney docket no. 25791.260.06, filed on 9/27/2005; (167) U.S. National Stage application serial no. 10/551880, attorney docket no. 25791.270.06, filed on 9/30/2005; (168) U.S. National Stage application serial no. 10/552253, attorney docket no. 25791.273.06, filed on 10/4/2005; (169) U.S. National Stage application serial no. 10/552790, attorney docket no. 25791.272.06, filed on 10/11/2005; (170) U.S. Provisional Patent Application No. 60/725181, attorney docket no. 25791.184 filed on 10/11/2005; (171) U.S. National Stage application serial no. 10/553094, attorney docket no. 25791.193.03, filed on 10/13/2005; (172) U.S.

National Stage application serial no. 10/553566, attorney docket no. 25791.277.06, filed on 10/17/05; (173) PCT Patent Application No. PCT/US2006/__________, attorney docket no. 25791.324.02 filed on 1/20/06, and (174) PCT Patent Application No. PCT/US2006/__________, attorney docket no. 25791.348.02 filed on 2/9/06; (175) U.S. Utility Patent application serial no. ____________________, attorney docket no. 25791.386, filed on 2/17/06, (176) U.S. National Stage application serial no. _________, attorney docket no. 25791.301.06, filed on ________, (177) U.S. National Stage application serial no. ____________, attorney docket no. 25791.137.04, filed on ___________, (178) U.S. National Stage application serial no. ____________, attorney docket no. 25791.215.06, (179) U.S. National State patent application serial no. _________, attorney docket no. 25791.305.05, filed on ___________; (180) U.S. National State patent application serial no. _________, attorney docket no. 25791.306.04, filed on ___________; (181) U.S. National State patent application serial no. _________, attorney docket no. 25791.307.04, filed on ___________; and (182) U.S. National State patent application serial no. _________, attorney docket no. 25791.308.07, filed on ___________, the disclosures of which are incorporated herein by reference.

Background of the Invention

[005] This invention relates generally to oil and gas exploration, and in particular to forming and repairing wellbore casings to facilitate oil and gas exploration.

Brief Description of the Drawings

[006] Fig. 1 is a fragmentary cross sectional view of an exemplary embodiment of an expandable tubular member positioned within a preexisting structure.

[007] Fig. 2 is a fragmentary cross sectional view of the expandable tubular member of Fig. 1 after positioning an expansion device within the expandable tubular member.

[008] Fig. 3 is a fragmentary cross sectional view of the expandable tubular member of Fig. 2 after operating the expansion device within the expandable tubular member to radially expand and plastically deform a portion of the expandable tubular member.

[009] Fig. 4 is a fragmentary cross sectional view of the expandable tubular member of Fig. 3 after operating the expansion device within the expandable tubular member to radially expand and plastically deform another portion of the expandable tubular member.

[0010] Fig. 5 is a graphical illustration of exemplary embodiments of the stress/strain curves for several portions of the expandable tubular member of Figs. 1-4.

[0011] Fig. 6 is a graphical illustration of the an exemplary embodiment of the yield strength vs. ductility curve for at least a portion of the expandable tubular member of Figs. 1-4.

[0012] Fig. 7 is a fragmentary cross sectional illustration of an embodiment of a series of overlapping expandable tubular members.

[0013] Fig. 8 is a fragmentary cross sectional view of an exemplary embodiment of an expandable tubular member positioned within a preexisting structure.

[0014] Fig. 9 is a fragmentary cross sectional view of the expandable tubular member of Fig. 8 after positioning an expansion device within the expandable tubular member.

[0015] Fig. 10 is a fragmentary cross sectional view of the expandable tubular member of Fig. 9 after operating the expansion device within the expandable tubular member to radially expand and plastically deform a portion of the expandable tubular member.

[0016] Fig. 11 is a fragmentary cross sectional view of the expandable tubular member of Fig. 10 after operating the expansion device within the expandable tubular member to radially expand and plastically deform another portion of the expandable tubular member.

[0017] Fig. 12 is a graphical illustration of exemplary embodiments of the stress/strain curves for several portions of the expandable tubular member of Figs. 8-11.

[0018] Fig. 13 is a graphical illustration of an exemplary embodiment of the yield strength vs. ductility curve for at least a portion of the expandable tubular member of Figs. 8-11.

[0019] Fig. 14 is a fragmentary cross sectional view of an exemplary embodiment of an expandable tubular member positioned within a preexisting structure.

[0020] Fig. 15 is a fragmentary cross sectional view of the expandable tubular member of Fig. 14 after positioning an expansion device within the expandable tubular member.

[0021] Fig. 16 is a fragmentary cross sectional view of the expandable tubular member of Fig. 15 after operating the expansion device within the expandable tubular member to radially expand and plastically deform a portion of the expandable tubular member.

[0022] Fig. 17 is a fragmentary cross sectional view of the expandable tubular member of Fig. 16 after operating the expansion device within the expandable tubular member to radially expand and plastically deform another portion of the expandable tubular member.

[0023] Fig. 18 is a flow chart illustration of an exemplary embodiment of a method of processing an expandable tubular member.

[0024] Fig. 19 is a graphical illustration of the an exemplary embodiment of the yield strength vs. ductility curve for at least a portion of the expandable tubular member during the operation of the method of Fig. 18.

[0025] Fig. 20 is a graphical illustration of stress/strain curves for an exemplary embodiment of an expandable tubular member.

[0026] Fig. 21 is a graphical illustration of stress/strain curves for an exemplary embodiment of an expandable tubular member.

[0027] Fig. 22 is a fragmentary cross-sectional view illustrating an embodiment of the radial expansion and plastic deformation of a portion of a first tubular member having an internally threaded connection at an end portion, an embodiment of a tubular sleeve supported by the end portion of the first tubular member, and a second tubular member

having an externally threaded portion coupled to the internally threaded portion of the first tubular member and engaged by a flange of the sleeve. The sleeve includes the flange at one end for increasing axial compression loading.

[0028] Fig. 23 is a fragmentary cross-sectional view illustrating an embodiment of the radial expansion and plastic deformation of a portion of a first tubular member having an internally threaded connection at an end portion, a second tubular member having an externally threaded portion coupled to the internally threaded portion of the first tubular member, and an embodiment of a tubular sleeve supported by the end portion of both tubular members. The sleeve includes flanges at opposite ends for increasing axial tension loading.

[0029] Fig. 24 is a fragmentary cross-sectional illustration of the radial expansion and plastic deformation of a portion of a first tubular member having an internally threaded connection at an end portion, a second tubular member having an externally threaded portion coupled to the internally threaded portion of the first tubular member, and an embodiment of a tubular sleeve supported by the end portion of both tubular members. The sleeve includes flanges at opposite ends for increasing axial compression/tension loading.

[0030] Fig. 25 is a fragmentary cross-sectional illustration of the radial expansion and plastic deformation of a portion of a first tubular member having an internally threaded connection at an end portion, a second tubular member having an externally threaded portion coupled to the internally threaded portion of the first tubular member, and an embodiment of a tubular sleeve supported by the end portion of both tubular members. The sleeve includes flanges at opposite ends having sacrificial material thereon.

[0031] Fig. 26 is a fragmentary cross-sectional illustration of the radial expansion and plastic deformation of a portion of a first tubular member having an internally threaded connection at an end portion, a second tubular member having an externally threaded portion coupled to the internally threaded portion of the first tubular member, and an embodiment of a tubular sleeve supported by the end portion of both tubular members. The sleeve includes a thin walled cylinder of sacrificial material.

[0032] Fig. 27 is a fragmentary cross-sectional illustration of the radial expansion and plastic deformation of a portion of a first tubular member having an internally threaded connection at an end portion, a second tubular member having an externally threaded portion coupled to the internally threaded portion of the first tubular member, and an embodiment of a tubular sleeve supported by the end portion of both tubular members. The sleeve includes a variable thickness along the length thereof.

[0033] Fig. 28 is a fragmentary cross-sectional illustration of the radial expansion and plastic deformation of a portion of a first tubular member having an internally threaded connection at an end portion, a second tubular member having an externally threaded portion coupled to the internally threaded portion of the first tubular member, and an embodiment of a tubular

sleeve supported by the end portion of both tubular members. The sleeve includes a member coiled onto grooves formed in the sleeve for varying the sleeve thickness.

[0034] Fig. 29 is a fragmentary cross-sectional illustration of an exemplary embodiment of an expandable connection.

[0035] Figs. 30a-30c are fragmentary cross-sectional illustrations of exemplary embodiments of expandable connections.

[0036] Fig. 31 is a fragmentary cross-sectional illustration of an exemplary embodiment of an expandable connection.

[0037] Figs. 32a and 32b are fragmentary cross-sectional illustrations of the formation of an exemplary embodiment of an expandable connection.

[0038] Fig. 33 is a fragmentary cross-sectional illustration of an exemplary embodiment of an expandable connection.

[0039] Figs. 34a, 34b and 34c are fragmentary cross-sectional illustrations of an exemplary embodiment of an expandable connection.

[0040] Fig. 35a is a fragmentary cross-sectional illustration of an exemplary embodiment of an expandable tubular member.

[0041] Fig. 35b is a graphical illustration of an exemplary embodiment of the variation in the yield point for the expandable tubular member of Fig. 35a.

[0042] Fig. 36a is a flow chart illustration of an exemplary embodiment of a method for processing a tubular member.

[0043] Fig. 36b is an illustration of the microstructure of an exemplary embodiment of a tubular member prior to thermal processing.

[0044] Fig. 36c is an illustration of the microstructure of an exemplary embodiment of a tubular member after thermal processing.

[0045] Fig. 37a is a flow chart illustration of an exemplary embodiment of a method for processing a tubular member.

[0046] Fig. 37b is an illustration of the microstructure of an exemplary embodiment of a tubular member prior to thermal processing.

[0047] Fig. 37c is an illustration of the microstructure of an exemplary embodiment of a tubular member after thermal processing.

[0048] Fig. 38a is a flow chart illustration of an exemplary embodiment of a method for processing a tubular member.

[0049] Fig. 38b is an illustration of the microstructure of an exemplary embodiment of a tubular member prior to thermal processing.

[0050] Fig. 38c is an illustration of the microstructure of an exemplary embodiment of a tubular member after thermal processing.

[0051] Fig. 39a is an illustration of exemplary tribological elements in a system for lubricating the interface between the expansion cone and a tubular member during the radial expansion and plastic deformation of the tubular member.

[0052] Fig. 39b is a fragmentary cross-sectional illustration of the lubrication of the interface between an expansion cone and a tubular member during the radial expansion process.

[0053] Fig. 40 is an illustration of an embodiment of an expansion cone including a system for lubricating the interface between the expansion cone and a tubular member during the radial expansion and plastic deformation of the tubular member.

[0054] Fig. 41 is an illustration of an embodiment of an expansion cone including a system for lubricating the interface between the expansion cone and a tubular member during the radial expansion and plastic deformation of the tubular member.

[0055] Fig. 42 is an illustration of an embodiment of an expansion cone including a system for lubricating the interface between the expansion cone and a tubular member during the radial expansion and plastic deformation of the tubular member.

[0056] Fig. 43 is an illustration of an embodiment of an expansion cone including a system for lubricating the interface between the expansion cone and a tubular member during the radial expansion and plastic deformation of the tubular member.

[0057] Fig. 44 is an illustration of an embodiment of an expansion cone including a system for lubricating the interface between the expansion cone and a tubular member during the radial expansion and plastic deformation of the tubular member.

[0058] Fig. 45 is an illustration of an embodiment of an expansion cone including a system for lubricating the interface between the expansion cone and a tubular member during the radial expansion and plastic deformation of the tubular member.

[0059] Fig. 46 is an illustration of an embodiment of an expansion cone including a system for lubricating the interface between the expansion cone and a tubular member during the radial expansion and plastic deformation of the tubular member.

[0060] Fig. 47 is an illustration of an embodiment of an expansion cone including a system for lubricating the interface between the expansion cone and a tubular member during the radial expansion and plastic deformation of the tubular member.

[0061] Fig. 48 is an illustration of an embodiment of an expansion cone including a system for lubricating the interface between the expansion cone and a tubular member during the radial expansion and plastic deformation of the tubular member.

[0062] Fig. 49 is an illustration of an embodiment of an expansion cone including a system for lubricating the interface between the expansion cone and a tubular member during the radial expansion and plastic deformation of the tubular member.

[0063] Fig. 50 is an illustration of an embodiment of an expansion cone including a system for lubricating the interface between the expansion cone and a tubular member during the radial expansion and plastic deformation of the tubular member.

[0064] Fig. 51 is an illustration of an embodiment of an expansion cone including a system for lubricating the interface between the expansion cone and a tubular member during the radial expansion and plastic deformation of the tubular member.

[0065] Fig. 52 is an illustration of an embodiment of an expansion cone including a system for lubricating the interface between the expansion cone and a tubular member during the radial expansion and plastic deformation of the tubular member.

[0066] Fig. 53 is an illustration of an embodiment of an expansion cone including a system for lubricating the interface between the expansion cone and a tubular member during the radial expansion and plastic deformation of the tubular member.

[0067] Fig. 54 is an illustration of an embodiment of an expansion cone including a system for lubricating the interface between the expansion cone and a tubular member during the radial expansion and plastic deformation of the tubular member.

[0068] Fig. 55 is a cross-sectional illustration of a circumferential groove suitable for use with the expansion cones of Figs. 40 - 54.

[0069] Fig. 56 is an illustration of the groove of Fig. 55.

[0070] Fig. 57 is an illustration of an alternate embodiment of the circumferential grove of the expansion cones of Figs. 40 - 57.

[0071] Fig. 58a is an elevational view of an embodiment of an expansion cone including a system for lubricating lubricating the interface between the expansion cone and a tubular member during the radial expansion and plastic deformation of the tubular member utilizing a groove designed in accordance with Figure 57.

[0072] Fig. 58b is a top view of the expansion cone of Fig. 58a.

[0073] Fig. 58c is an enlarged section of the expansion cone of Fig. 58a.

[0074] Fig. 59a is an illustration of an embodiment of an expansion cone including a system for lubricating the interface between the expansion cone and a tubular member during the radial expansion and plastic deformation of the tubular member.

[0075] Fig. 59b is a top view of the expansion cone of Fig. 59a.

[0076] Fig. 60a is an illustration of an embodiment of an expansion cone including a system for lubricating the interface between the expansion cone having a tapered faceted polygonal outer expansion surface and a tubular member during the radial expansion and plastic deformation of the tubular member.

[0077] Fig. 60b is a top view of the expansion cone in Fig. 60a.

[0078] Fig. 60c is a fragmentary cross-sectional illustration of the expansion cone in Fig. 60a in a tubular member.

[0079] Figs. 61a and 61b are cross-sectional illustrations of an alternate embodiment of tubular member and an expansion cone including a system for lubricating the interface between the expansion cone having a tapered faceted polygonal outer expansion surface and a tubular member during the radial expansion and plastic deformation of the tubular member.

[0080] Figs. 61c and 61d are cross-sectional illustrations of an alternate embodiment of an expansion cone including a system for lubricating the interface between the expansion cone having a tapered faceted polygonal outer expansion surface and a tubular member during the radial expansion and plastic deformation of the tubular member.

[0081] Fig. 61e is cross-sectional illustrations of an alternate embodiment of an expansion cone including a system for lubricating the interface between the expansion cone having a tapered faceted polygonal outer expansion surface and a tubular member having non-uniform wall thickness during the radial expansion and plastic deformation of the tubular member.

[0082] Fig. 62a, 62b, and 62c are an illustrations of an alternate embodiment of an expansion cone including a system for lubricating the interface between the expansion cone having a tapered faceted polygonal outer expansion surface and a tubular member during the radial expansion and plastic deformation of the tubular member.

[0083] Fig. 62d, 62e, and 62f are an illustrations of an alternate embodiment of an expansion cone including a system for lubricating the interface between the expansion cone having a tapered faceted polygonal outer expansion surface and a tubular member during the radial expansion and plastic deformation of the tubular member.

[0084] Fig. 63 is a cross-sectional illustration of an embodiment of a system for lubricating the interface between the expansion cone and a tubular member during the radial expansion and plastic deformation of the tubular member.

[0085] Fig. 64 is a cross-sectional illustration of an embodiment of a system for lubricating the interface between the expansion cone and a tubular member during the radial expansion and plastic deformation of the tubular member.

[0086] Fig. 65 is a cross-sectional illustration of an embodiment of a system for lubricating the interface between the expansion cone and a tubular member during the radial expansion and plastic deformation of the tubular member.

[0087] Fig. 66 is a cross-sectional illustration of an embodiment of a system for lubricating the interface between the expansion cone and a tubular member during the radial expansion and plastic deformation of the tubular member.

[0088] Fig. 67 is a cross-sectional illustration of an embodiment of a system for lubricating the interface between the expansion cone and a tubular member during the radial expansion and plastic deformation of the tubular member.

[0089] Fig. 68 is a cross-sectional illustration of an embodiment of a system for lubricating the interface between the expansion cone and a tubular member during the radial expansion and plastic deformation of the tubular member.

[0090] Fig. 69 is a cross-sectional illustration of an embodiment of a system for lubricating the interface between the expansion cone and a tubular member during the radial expansion and plastic deformation of the tubular member.

[0091] Fig. 70 is a cross-sectional illustration of an embodiment of a system for lubricating the interface between the expansion cone and a tubular member during the radial expansion and plastic deformation of the tubular member.

[0092] Figs. 71a, 71b, 71c, 71d and 71e are graphical illustrations of example expansion cone materials characteristics.

[0093] Fig. 72 is a flow chart illustration of an exemplary embodiment of a method for processing a tubular member.

[0094] Fig. 73a is a fragmentary cross-sectional illustration of example frictional forces in a system including an expansion cone and a tubular member during the radial expansion and plastic deformation of the tubular member.

[0095] Fig. 73b is a fragmentary cross-sectional illustration of an example components in a system including an expansion cone and a tubular member during the radial expansion and plastic deformation of the tubular member that contribute to the frictional forces.

[0096] Figs. 73c and 73d are fragmentary cross-sectional illustrations of example expansion cone surface roughness and texture characteristics in a system including an expansion cone and a tubular member during the radial expansion and plastic deformation of the tubular member that contribute to the frictional forces.

[0097] Fig. 74 is a graphical illustration of a coefficient of friction versus expansion force in an exemplary system for radially expanding a tubular member.

[0098] Fig. 75 is a graphical logarithmic illustration of the coefficient of friction versus expansion force (in pounds per square inch) in an exemplary system for radially expanding a tubular member.

[0099] Fig. 76 is a graphical logarithmic illustration of the coefficient of friction versus expansion force (in pounds) in an exemplary system for radially expanding a tubular member.

[00100] Fig. 77 is a graphical illustration of the expansion forces in an exemplary system for radially expanding a tubular member over time.

[00101] Fig. 78 is a graphical illustration the range of coefficients of friction for exemplary systems for radially expanding a tubular member.

[00102] Fig. 79a and 79b are photo-micrograph illustrations of the microstructure of an exemplary embodiments of expansion cones.

[00103] Figs. 80a and 80b are photo-micrograph illustrations of the microstructure of the exemplary embodiments of expansion cones shown in Figs. 79a and 79b, respectively.

[00104] Figs. 81a and 81b are graphical illustrations of the x-profile of the exemplary embodiments of expansion cones shown in Figs. 79a and 79b, respectively.

[00105] Figs. 82a and 82b are graphical illustrations of the bearing ratio of the exemplary embodiments of expansion cones shown in Figs. 79a and 79b, respectively.

[00106] Figs. 83a and 83b are photo-micrograph illustrations of the microstructure of an exemplary embodiments of expansion cones.

[00107] Figs. 84a and 84b are photo-micrograph illustrations of the microstructure of the exemplary embodiments of expansion cones shown in Figs. 83a and 83b, respectively.

[00108] Figs. 85a and 85b are graphical illustrations of the x-profile of the exemplary embodiments of expansion cones shown in Figs. 83a and 83b, respectively.

[00109] Figs. 86a and 86b are graphical illustrations of the bearing ratio of the exemplary embodiments of expansion cones shown in Figs. 83a and 83b, respectively.

[00110] Fig. 87 is a graphical illustration ranges of expansion forces associated with exemplary systems for radially expanding a tubular member.

[00111] Fig. 88 is a graphical illustration ranges of expansion forces associated with exemplary systems for radially expanding a tubular member.

[00112] Fig. 89 is a graphical illustration ranges of expansion forces associated with exemplary systems for radially expanding a tubular member.

[00113] Fig. 90 is a graphical illustration ranges of expansion forces associated with exemplary systems for radially expanding a tubular member.

[00114] Fig. 91 is a graphical illustration ranges of expansion forces associated with exemplary systems for radially expanding a tubular member.

[00115] Fig. 92 is a graphical illustration ranges of expansion forces associated with exemplary systems for radially expanding a tubular member.

[00116] Fig. 93 is a graphical illustration ranges of expansion forces associated with exemplary systems for radially expanding a tubular member.

[00117] Fig. 94 is a graphical illustration ranges of expansion forces associated with exemplary systems for radially expanding a tubular member.

[00118] Fig. 95 is a graphical illustration ranges of expansion forces associated with exemplary systems for radially expanding a tubular member.

[00119] Fig. 96 is a graphical illustration ranges of expansion forces associated with exemplary systems for radially expanding a tubular member.

[00120] Fig. 97 is a graphical illustration ranges of expansion forces associated with exemplary systems for radially expanding a tubular member.

[00121] Fig. 98 is a graphical illustration ranges of expansion forces associated with exemplary systems for radially expanding a tubular member.

[00122] Fig. 99a is an illustration of an embodiment of an expansion cone including a system for lubricating the interface between the expansion cone and a tubular member during the radial expansion and plastic deformation of the tubular member.

[00123] Fig. 99b are photo-micrograph illustrations of the microstructure of an exemplary embodiments of expansion cones.

[00124] Fig. 99c is an illustration of an embodiment of a system for lubricating the interface between the expansion cone and a tubular member during the radial expansion and plastic deformation of the tubular member.

[00125] Fig. 100 is a schematic fragmentary cross-sectional view along a plane along and through the central axis of a tubular member that is tested to failure with axial opposed forces.

[00126] Fig. 101 is a stress-strain curve representing values for stress and strain that may be plotted for solid specimen sample.

[00127] Fig. 102 is a schematically depiction of a stress strain curve representing values from an exemplary test on a tubular member.

[00128] Fig. 103 is a graphical illustration of an exemplary experimental embodiment.

[00129] Fig. 104 is a graphical illustration of an exemplary experimental embodiment.

[00130] Fig. 105 is a flow chart illustration of an exemplary embodiment of a method of processing tubular members.

[00131] Fig. 106 is a graphical illustration of an exemplary embodiment of a method of processing tubular members.

[00132] Fig. 107 is a graphical illustration of an exemplary embodiment of a method of processing tubular members.

[00133] Fig. 108 is a graphical illustration of an exemplary embodiment of a method of processing tubular members.

Detailed Description of the Illustrative Embodiments

[00134] Referring initially to Fig. 1, an exemplary embodiment of an expandable tubular assembly 10 includes a first expandable tubular member 12 coupled to a second expandable tubular member 14. In several exemplary embodiments, the ends of the first and second expandable tubular members, 12 and 14, are coupled using, for example, a conventional mechanical coupling, a welded connection, a brazed connection, a threaded connection, and/or an interference fit connection. In an exemplary embodiment, the first expandable tubular member 12 has a plastic yield point YP_1, and the second expandable tubular member 14 has a plastic yield point YP_2. In an exemplary embodiment, the expandable tubular assembly 10 is positioned within a preexisting structure such as, for

example, a wellbore 16 that traverses a subterranean formation 18.

[00135] As illustrated in Fig. 2, an expansion device 20 may then be positioned within the second expandable tubular member 14. In several exemplary embodiments, the expansion device 20 may include, for example, one or more of the following conventional expansion devices: a) an expansion cone; b) a rotary expansion device; c) a hydroforming expansion device; d) an impulsive force expansion device; d) any one of the expansion devices commercially available from, or disclosed in any of the published patent applications or issued patents, of Weatherford International, Baker Hughes, Halliburton Energy Services, Shell Oil Co., Schlumberger, and/or Enventure Global Technology L.L.C. In several exemplary embodiments, the expansion device 20 is positioned within the second expandable tubular member 14 before, during, or after the placement of the expandable tubular assembly 10 within the preexisting structure 16.

[00136] As illustrated in Fig. 3, the expansion device 20 may then be operated to radially expand and plastically deform at least a portion of the second expandable tubular member 14 to form a bell-shaped section.

[00137] As illustrated in Fig. 4, the expansion device 20 may then be operated to radially expand and plastically deform the remaining portion of the second expandable tubular member 14 and at least a portion of the first expandable tubular member 12.

[00138] In an exemplary embodiment, at least a portion of at least a portion of at least one of the first and second expandable tubular members, 12 and 14, are radially expanded into intimate contact with the interior surface of the preexisting structure 16.

[00139] In an exemplary embodiment, as illustrated in Fig. 5, the plastic yield point YP_1 is greater than the plastic yield point YP_2. In this manner, in an exemplary embodiment, the amount of power and/or energy required to radially expand the second expandable tubular member 14 is less than the amount of power and/or energy required to radially expand the first expandable tubular member 12.

[00140] In an exemplary embodiment, as illustrated in Fig. 6, the first expandable tubular member 12 and/or the second expandable tubular member 14 have a ductility D_{PE} and a yield strength YS_{PE} prior to radial expansion and plastic deformation, and a ductility D_{AE} and a yield strength YS_{AE} after radial expansion and plastic deformation. In an exemplary embodiment, D_{PE} is greater than D_{AE}, and YS_{AE} is greater than YS_{PE}. In this manner, the first expandable tubular member 12 and/or the second expandable tubular member 14 are transformed during the radial expansion and plastic deformation process. Furthermore, in this manner, in an exemplary embodiment, the amount of power and/or energy required to radially expand each unit length of the first and/or second expandable tubular members, 12 and 14, is reduced. Furthermore, because the YS_{AE} is greater than YS_{PE}, the collapse strength of the first expandable tubular member 12 and/or the second expandable tubular

member 14 is increased after the radial expansion and plastic deformation process.

[00141] In an exemplary embodiment, as illustrated in Fig. 7, following the completion of the radial expansion and plastic deformation of the expandable tubular assembly 10 described above with reference to Figs. 1-4, at least a portion of the second expandable tubular member 14 has an inside diameter that is greater than at least the inside diameter of the first expandable tubular member 12. In this manner a bell-shaped section is formed using at least a portion of the second expandable tubular member 14. Another expandable tubular assembly 22 that includes a first expandable tubular member 24 and a second expandable tubular member 26 may then be positioned in overlapping relation to the first expandable tubular assembly 10 and radially expanded and plastically deformed using the methods described above with reference to Figs. 1-4. Furthermore, following the completion of the radial expansion and plastic deformation of the expandable tubular assembly 20, in an exemplary embodiment, at least a portion of the second expandable tubular member 26 has an inside diameter that is greater than at least the inside diameter of the first expandable tubular member 24. In this manner a bell-shaped section is formed using at least a portion of the second expandable tubular member 26. Furthermore, in this manner, a mono-diameter tubular assembly is formed that defines an internal passage 28 having a substantially constant cross-sectional area and/or inside diameter.

[00142] Referring to Fig. 8, an exemplary embodiment of an expandable tubular assembly 100 includes a first expandable tubular member 102 coupled to a tubular coupling 104. The tubular coupling 104 is coupled to a tubular coupling 106. The tubular coupling 106 is coupled to a second expandable tubular member 108. In several exemplary embodiments, the tubular couplings, 104 and 106, provide a tubular coupling assembly for coupling the first and second expandable tubular members, 102 and 108, together that may include, for example, a conventional mechanical coupling, a welded connection, a brazed connection, a threaded connection, and/or an interference fit connection. In an exemplary embodiment, the first and second expandable tubular members 12 have a plastic yield point YP_1, and the tubular couplings, 104 and 106, have a plastic yield point YP_2. In an exemplary embodiment, the expandable tubular assembly 100 is positioned within a preexisting structure such as, for example, a wellbore 110 that traverses a subterranean formation 112.

[00143] As illustrated in Fig. 9, an expansion device 114 may then be positioned within the second expandable tubular member 108. In several exemplary embodiments, the expansion device 114 may include, for example, one or more of the following conventional expansion devices: a) an expansion cone; b) a rotary expansion device; c) a hydroforming expansion device; d) an impulsive force expansion device; d) any one of the expansion devices commercially available from, or disclosed in any of the published patent applications or issued patents, of Weatherford International, Baker Hughes, Halliburton Energy Services,

Shell Oil Co., Schlumberger, and/or Enventure Global Technology L.L.C. In several exemplary embodiments, the expansion device 114 is positioned within the second expandable tubular member 108 before, during, or after the placement of the expandable tubular assembly 100 within the preexisting structure 110.

[00144] As illustrated in Fig. 10, the expansion device 114 may then be operated to radially expand and plastically deform at least a portion of the second expandable tubular member 108 to form a bell-shaped section.

[00145] As illustrated in Fig. 11, the expansion device 114 may then be operated to radially expand and plastically deform the remaining portion of the second expandable tubular member 108, the tubular couplings, 104 and 106, and at least a portion of the first expandable tubular member 102.

[00146] In an exemplary embodiment, at least a portion of at least a portion of at least one of the first and second expandable tubular members, 102 and 108, are radially expanded into intimate contact with the interior surface of the preexisting structure 110.

[00147] In an exemplary embodiment, as illustrated in Fig. 12, the plastic yield point YP_1 is less than the plastic yield point YP_2. In this manner, in an exemplary embodiment, the amount of power and/or energy required to radially expand each unit length of the first and second expandable tubular members, 102 and 108, is less than the amount of power and/or energy required to radially expand each unit length of the tubular couplings, 104 and 106.

[00148] In an exemplary embodiment, as illustrated in Fig. 13, the first expandable tubular member 12 and/or the second expandable tubular member 14 have a ductility D_{PE} and a yield strength YS_{PE} prior to radial expansion and plastic deformation, and a ductility D_{AE} and a yield strength YS_{AE} after radial expansion and plastic deformation. In an exemplary embodiment, D_{PE} is greater than D_{AE}, and YS_{AE} is greater than YS_{PE}. In this manner, the first expandable tubular member 12 and/or the second expandable tubular member 14 are transformed during the radial expansion and plastic deformation process. Furthermore, in this manner, in an exemplary embodiment, the amount of power and/or energy required to radially expand each unit length of the first and/or second expandable tubular members, 12 and 14, is reduced. Furthermore, because the YS_{AE} is greater than YS_{PE}, the collapse strength of the first expandable tubular member 12 and/or the second expandable tubular member 14 is increased after the radial expansion and plastic deformation process.

[00149] Referring to Fig. 14, an exemplary embodiment of an expandable tubular assembly 200 includes a first expandable tubular member 202 coupled to a second expandable tubular member 204 that defines radial openings 204a, 204b, 204c, and 204d. In several exemplary embodiments, the ends of the first and second expandable tubular members, 202 and 204, are coupled using, for example, a conventional mechanical coupling, a welded connection, a brazed connection, a threaded connection, and/or an

interference fit connection. In an exemplary embodiment, one or more of the radial openings, 204a, 204b, 204c, and 204d, have circular, oval, square, and/or irregular cross sections and/or include portions that extend to and interrupt either end of the second expandable tubular member 204. In an exemplary embodiment, the expandable tubular assembly 200 is positioned within a preexisting structure such as, for example, a wellbore 206 that traverses a subterranean formation 208.

[00150] As illustrated in Fig. 15, an expansion device 210 may then be positioned within the second expandable tubular member 204. In several exemplary embodiments, the expansion device 210 may include, for example, one or more of the following conventional expansion devices: a) an expansion cone; b) a rotary expansion device; c) a hydroforming expansion device; d) an impulsive force expansion device; d) any one of the expansion devices commercially available from, or disclosed in any of the published patent applications or issued patents, of Weatherford International, Baker Hughes, Halliburton Energy Services, Shell Oil Co., Schlumberger, and/or Enventure Global Technology L.L.C. In several exemplary embodiments, the expansion device 210 is positioned within the second expandable tubular member 204 before, during, or after the placement of the expandable tubular assembly 200 within the preexisting structure 206.

[00151] As illustrated in Fig. 16, the expansion device 210 may then be operated to radially expand and plastically deform at least a portion of the second expandable tubular member 204 to form a bell-shaped section.

[00152] As illustrated in Fig. 16, the expansion device 20 may then be operated to radially expand and plastically deform the remaining portion of the second expandable tubular member 204 and at least a portion of the first expandable tubular member 202.

[00153] In an exemplary embodiment, the anisotropy ratio AR for the first and second expandable tubular members is defined by the following equation:

a. $AR = \ln (WT_f/WT_o)/\ln (D_f/D_o)$; (1)
b. where AR = anisotropy ratio;
c. where WT_f = final wall thickness of the expandable tubular member following the radial expansion and plastic deformation of the expandable tubular member;
d. where WT_i = initial wall thickness of the expandable tubular member prior to the radial expansion and plastic deformation of the expandable tubular member;
e. where D_f = final inside diameter of the expandable tubular member following the radial expansion and plastic deformation of the expandable tubular member; and
f. where D_i = initial inside diameter of the expandable tubular member prior to

the radial expansion and plastic deformation of the expandable tubular member.

[00154] In an exemplary embodiment, the anisotropy ratio AR for the first and/or second expandable tubular members, 204 and 204, is greater than 1.

[00155] In an exemplary experimental embodiment, the second expandable tubular member 204 had an anisotropy ratio AR greater than 1, and the radial expansion and plastic deformation of the second expandable tubular member did not result in any of the openings, 204a, 204b, 204c, and 204d, splitting or otherwise fracturing the remaining portions of the second expandable tubular member. This was an unexpected result.

[00156] Referring to Fig. 18, in an exemplary embodiment, one or more of the expandable tubular members, 12, 14, 24, 26, 102, 104, 106, 108, 202 and/or 204 are processed using a method 300 in which a tubular member in an initial state is thermo-mechanically processed in step 302. In an exemplary embodiment, the thermo-mechanical processing 302 includes one or more heat treating and/or mechanical forming processes. As a result, of the thermo-mechanical processing 302, the tubular member is transformed to an intermediate state. The tubular member is then further thermo-mechanically processed in step 304. In an exemplary embodiment, the thermo-mechanical processing 304 includes one or more heat treating and/or mechanical forming processes. As a result, of the thermo-mechanical processing 304, the tubular member is transformed to a final state.

[00157] In an exemplary embodiment, as illustrated in Fig. 19, during the operation of the method 300, the tubular member has a ductility D_{PE} and a yield strength YS_{PE} prior to the final thermo-mechanical processing in step 304, and a ductility D_{AE} and a yield strength YS_{AE} after final thermo-mechanical processing. In an exemplary embodiment, D_{PE} is greater than D_{AE}, and YS_{AE} is greater than YS_{PE}. In this manner, the amount of energy and/or power required to transform the tubular member, using mechanical forming processes, during the final thermo-mechanical processing in step 304 is reduced. Furthermore, in this manner, because the YS_{AE} is greater than YS_{PE}, the collapse strength of the tubular member is increased after the final thermo-mechanical processing in step 304.

[00158] In an exemplary embodiment, one or more of the expandable tubular members, 12, 14, 24, 26, 102, 104, 106, 108, 202 and/or 204, have the following characteristics:

Characteristic	Value
Tensile Strength	60 to 120 ksi
Yield Strength	50 to 100 ksi
Y/T Ratio	Maximum of 50/85 %

Characteristic	Value
Elongation During Radial Expansion and Plastic Deformation	Minimum of 35 %
Width Reduction During Radial Expansion and Plastic Deformation	Minimum of 40 %
Wall Thickness Reduction During Radial Expansion and Plastic Deformation	Minimum of 30 %
Anisotropy	Minimum of 1.5
Minimum Absorbed Energy at -4 F (-20 C) in the Longitudinal Direction	80 ft-lb
Minimum Absorbed Energy at -4 F (-20 C) in the Transverse Direction	60 ft-lb
Minimum Absorbed Energy at -4 F (-20 C) Transverse To A Weld Area	60 ft-lb
Flare Expansion Testing	Minimum of 75% Without A Failure
Increase in Yield Strength Due To Radial Expansion and Plastic Deformation	Greater than 5.4 %

[00159] In an exemplary embodiment, one or more of the expandable tubular members, 12, 14, 24, 26, 102, 104, 106, 108, 202 and/or 204, are characterized by an expandability coefficient f:

i. $f = r \times n$ (2)

ii. where f = expandability coefficient;

1. r = anisotropy coefficient; and
2. n = strain hardening exponent.

[00160] In an exemplary embodiment, the anisotropy coefficient for one or more of the expandable tubular members, 12, 14, 24, 26, 102, 104, 106, 108, 202 and/or 204 is greater than 1. In an exemplary embodiment, the strain hardening exponent for one or more of the expandable tubular members, 12, 14, 24, 26, 102, 104, 106, 108, 202 and/or 204 is greater than 0.12. In an exemplary embodiment, the expandability coefficient for one or more of the expandable tubular members, 12, 14, 24, 26, 102, 104, 106, 108, 202 and/or 204 is greater

than 0.12.

[00161] In an exemplary embodiment, a tubular member having a higher expandability coefficient requires less power and/or energy to radially expand and plastically deform each unit length than a tubular member having a lower expandability coefficient. In an exemplary embodiment, a tubular member having a higher expandability coefficient requires less power and/or energy per unit length to radially expand and plastically deform than a tubular member having a lower expandability coefficient.

[00162] In several exemplary experimental embodiments, one or more of the expandable tubular members, 12, 14, 24, 26, 102, 104, 106, 108, 202 and/or 204, are steel alloys having one of the following compositions:

	Element and Percentage By Weight							
Steel Alloy	**C**	**Mn**	**P**	**S**	**Si**	**Cu**	**Ni**	**Cr**
A	0.065	1.44	0.01	0.002	0.24	0.01	0.01	0.02
B	0.18	1.28	0.017	0.004	0.29	0.01	0.01	0.03
C	0.08	0.82	0.006	0.003	0.30	0.16	0.05	0.05
D	0.02	1.31	0.02	0.001	0.45	-	9.1	18.7

[00163] In exemplary experimental embodiment, as illustrated in Fig. 20, a sample of an expandable tubular member composed of Alloy A exhibited a yield point before radial expansion and plastic deformation YP_{BE}, a yield point after radial expansion and plastic deformation of about 16 % $YP_{AE16\%}$, and a yield point after radial expansion and plastic deformation of about 24 % $YP_{AE24\%}$. In an exemplary experimental embodiment, $YP_{AE24\%} > YP_{AE16\%} > YP_{BE}$. Furthermore, in an exemplary experimental embodiment, the ductility of the sample of the expandable tubular member composed of Alloy A also exhibited a higher ductility prior to radial expansion and plastic deformation than after radial expansion and plastic deformation. These were unexpected results.

[00164] In an exemplary experimental embodiment, a sample of an expandable tubular member composed of Alloy A exhibited the following tensile characteristics before and after radial expansion and plastic deformation:

	Yield Point ksi	**Yield Ratio**	**Elongation %**	**Width Reduction %**	**Wall Thickness Reduction %**	**Anisotropy**
Before Radial	46.9	0.69	53	-52	55	0.93

	Yield Point ksi	Yield Ratio	Elongation %	Width Reduction %	Wall Thickness Reduction %	Anisotropy
Expansion and Plastic Deformation						
After 16% Radial Expansion	65.9	0.83	17	42	51	0.78
After 24% Radial Expansion	68.5	0.83	5	44	54	0.76
% Increase	40% for 16% radial expansion 46% for 24% radial expansion					

[00165] In exemplary experimental embodiment, as illustrated in Fig. 21, a sample of an expandable tubular member composed of Alloy B exhibited a yield point before radial expansion and plastic deformation YP_{BE}, a yield point after radial expansion and plastic deformation of about 16 % $YP_{AE16\%}$, and a yield point after radial expansion and plastic deformation of about 24 % $YP_{AE24\%}$. In an exemplary embodiment, $YP_{AE24\%} > YP_{AE16\%} > YP_{BE}$. Furthermore, in an exemplary experimental embodiment, the ductility of the sample of the expandable tubular member composed of Alloy B also exhibited a higher ductility prior to radial expansion and plastic deformation than after radial expansion and plastic deformation. These were unexpected results.

[00166] In an exemplary experimental embodiment, a sample of an expandable tubular member composed of Alloy B exhibited the following tensile characteristics before and after radial expansion and plastic deformation:

	Yield Point ksi	Yield Ratio	Elongation %	Width Reduction %	Wall Thickness Reduction %	Anisotropy
Before Radial Expansion and Plastic Deformation	57.8	0.71	44	43	46	0.93
After 16% Radial Expansion	74.4	0.84	16	38	42	0.87
After 24% Radial Expansion	79.8	0.86	20	36	42	0.81
% Increase	28.7% increase for 16% radial expansion 38% increase for 24% radial expansion					

[00167] In an exemplary experimental embodiment, samples of expandable tubulars composed of Alloys A, B, C, and D exhibited the following tensile characteristics prior to radial expansion and plastic deformation:

Steel Alloy	Yield ksi	Yield Ratio	Elongation %	Anisotropy	Absorbed Energy ft-lb	Expandability Coefficient
A	47.6	0.71	44	1.48	145	
B	57.8	0.71	44	1.04	62.2	
C	61.7	0.80	39	1.92	268	
D	48	0.55	56	1.34	-	

[00168] In an exemplary embodiment, one or more of the expandable tubular members, 12, 14, 24, 26, 102, 104, 106, 108, 202 and/or 204 have a strain hardening exponent greater than 0.12, and a yield ratio is less than 0.85.

[00169] In an exemplary embodiment, the carbon equivalent C_e, for tubular members having a carbon content (by weight percentage) less than or equal to 0.12%, is given by the following expression:

$$C_e = C + Mn/6 + (Cr + Mo + V + Ti + Nb)/5 + (Ni + Cu)/15 \qquad (3)$$

where C_e = carbon equivalent value;

b. C = carbon percentage by weight;

c. Mn = manganese percentage by weight;

d. Cr = chromium percentage by weight;

e. Mo = molybdenum percentage by weight;

f. V = vanadium percentage by weight;

g. Ti = titanium percentage by weight;

h. Nb = niobium percentage by weight;

i. Ni = nickel percentage by weight; and

j. Cu = copper percentage by weight.

[00170] In an exemplary embodiment, the carbon equivalent value C_e, for tubular members having a carbon content less than or equal to 0.12% (by weight), for one or more of the expandable tubular members, 12, 14, 24, 26, 102, 104, 106, 108, 202 and/or 204 is less than 0.21.

[00171] In an exemplary embodiment, the carbon equivalent C_e, for tubular members having more than 0.12% carbon content (by weight), is given by the following expression:

$$C_e = C + Si/30 + (Mn + Cu + Cr)/20 + Ni/60 + Mo/15 + V/10 + 5*B \qquad (4)$$

where C_e = carbon equivalent value;

k. C = carbon percentage by weight;

l. Si = silicon percentage by weight;

m. Mn = manganese percentage by weight;

n. Cu = copper percentage by weight;

o. Cr = chromium percentage by weight;

p. Ni = nickel percentage by weight;

q. Mo = molybdenum percentage by weight;

r. V = vanadium percentage by weight; and

s. B = boron percentage by weight.

[00172] In an exemplary embodiment, the carbon equivalent value C_e, for tubular

members having greater than 0.12% carbon content (by weight), for one or more of the expandable tubular members, 12, 14, 24, 26, 102, 104, 106, 108, 202 and/or 204 is less than 0.36.

[00173] Referring to Fig. 22 in an exemplary embodiment, a first tubular member 2210 includes an internally threaded connection 2212 at an end portion 2214. A first end of a tubular sleeve 2216 that includes an internal flange 2218 having a tapered portion 2220, and a second end that includes a tapered portion 2222, is then mounted upon and receives the end portion 2214 of the first tubular member 2210. In an exemplary embodiment, the end portion 2214 of the first tubular member 2210 abuts one side of the internal flange 2218 of the tubular sleeve 2216, and the internal diameter of the internal flange 2218 of the tubular sleeve 2216 is substantially equal to or greater than the maximum internal diameter of the internally threaded connection 2212 of the end portion 2214 of the first tubular member 2210. An externally threaded connection 2224 of an end portion 2226 of a second tubular member 2228 having an annular recess 2230 is then positioned within the tubular sleeve 2216 and threadably coupled to the internally threaded connection 2212 of the end portion 2214 of the first tubular member 2210. In an exemplary embodiment, the internal flange 2218 of the tubular sleeve 2216 mates with and is received within the annular recess 2230 of the end portion 2226 of the second tubular member 2228. Thus, the tubular sleeve 2216 is coupled to and surrounds the external surfaces of the first and second tubular members, 2210 and 2228.

[00174] The internally threaded connection 2212 of the end portion 2214 of the first tubular member 2210 is a box connection, and the externally threaded connection 2224 of the end portion 2226 of the second tubular member 2228 is a pin connection. In an exemplary embodiment, the internal diameter of the tubular sleeve 2216 is at least approximately .020" greater than the outside diameters of the first and second tubular members, 2210 and 2228. In this manner, during the threaded coupling of the first and second tubular members, 2210 and 2228, fluidic materials within the first and second tubular members may be vented from the tubular members.

[00175] As illustrated in Fig. 22, the first and second tubular members, 2210 and 2228, and the tubular sleeve 2216 may be positioned within another structure 2232 such as, for example, a cased or uncased wellbore, and radially expanded and plastically deformed, for example, by displacing and/or rotating a conventional expansion device 2234 within and/or through the interiors of the first and second tubular members. The tapered portions, 2220 and 2222, of the tubular sleeve 2216 facilitate the insertion and movement of the first and second tubular members within and through the structure 2232, and the movement of the expansion device 2234 through the interiors of the first and second tubular members, 2210 and 2228, may be, for example, from top to bottom or from bottom to top.

[00176] During the radial expansion and plastic deformation of the first and second tubular members, 2210 and 2228, the tubular sleeve 2216 is also radially expanded and plastically deformed. As a result, the tubular sleeve 2216 may be maintained in circumferential tension and the end portions, 2214 and 2226, of the first and second tubular members, 2210 and 2228, may be maintained in circumferential compression.

[00177] Sleeve 2216 increases the axial compression loading of the connection between tubular members 2210 and 2228 before and after expansion by the expansion device 2234. Sleeve 2216 may, for example, be secured to tubular members 2210 and 2228 by a heat shrink fit.

[00178] In several alternative embodiments, the first and second tubular members, 2210 and 2228, are radially expanded and plastically deformed using other conventional methods for radially expanding and plastically deforming tubular members such as, for example, internal pressurization, hydroforming, and/or roller expansion devices and/or any one or combination of the conventional commercially available expansion products and services available from Baker Hughes, Weatherford International, and/or Enventure Global Technology L.L.C.

[00179] The use of the tubular sleeve 2216 during (a) the coupling of the first tubular member 2210 to the second tubular member 2228, (b) the placement of the first and second tubular members in the structure 2232, and (c) the radial expansion and plastic deformation of the first and second tubular members provides a number of significant benefits. For example, the tubular sleeve 2216 protects the exterior surfaces of the end portions, 2214 and 2226, of the first and second tubular members, 2210 and 2228, during handling and insertion of the tubular members within the structure 2232. In this manner, damage to the exterior surfaces of the end portions, 2214 and 2226, of the first and second tubular members, 2210 and 2228, is avoided that could otherwise result in stress concentrations that could cause a catastrophic failure during subsequent radial expansion operations. Furthermore, the tubular sleeve 2216 provides an alignment guide that facilitates the insertion and threaded coupling of the second tubular member 2228 to the first tubular member 2210. In this manner, misalignment that could result in damage to the threaded connections, 2212 and 2224, of the first and second tubular members, 2210 and 2228, may be avoided. In addition, during the relative rotation of the second tubular member with respect to the first tubular member, required during the threaded coupling of the first and second tubular members, the tubular sleeve 2216 provides an indication of to what degree the first and second tubular members are threadably coupled. For example, if the tubular sleeve 2216 can be easily rotated, that would indicate that the first and second tubular members, 2210 and 2228, are not fully threadably coupled and in intimate contact with the internal flange 2218 of the tubular sleeve. Furthermore, the tubular sleeve 2216 may

prevent crack propagation during the radial expansion and plastic deformation of the first and second tubular members, 2210 and 2228. In this manner, failure modes such as, for example, longitudinal cracks in the end portions, 2214 and 2226, of the first and second tubular members may be limited in severity or eliminated all together. In addition, after completing the radial expansion and plastic deformation of the first and second tubular members, 2210 and 2228, the tubular sleeve 2216 may provide a fluid tight metal-to-metal seal between interior surface of the tubular sleeve 2216 and the exterior surfaces of the end portions, 2214 and 2226, of the first and second tubular members. In this manner, fluidic materials are prevented from passing through the threaded connections, 2212 and 2224, of the first and second tubular members, 2210 and 2228, into the annulus between the first and second tubular members and the structure 2232. Furthermore, because, following the radial expansion and plastic deformation of the first and second tubular members, 2210 and 2228, the tubular sleeve 2216 may be maintained in circumferential tension and the end portions, 2214 and 2226, of the first and second tubular members, 2210 and 2228, may be maintained in circumferential compression, axial loads and/or torque loads may be transmitted through the tubular sleeve.

[00180] In several exemplary embodiments, one or more portions of the first and second tubular members, 2210 and 2228, and the tubular sleeve 2216 have one or more of the material properties of one or more of the tubular members 12, 14, 24, 26, 102, 104, 106, 108, 202 and/or 204.

[00181] Referring to Fig. 23, in an exemplary embodiment, a first tubular member 210 includes an internally threaded connection 2312 at an end portion 2314. A first end of a tubular sleeve 2316 includes an internal flange 2318 and a tapered portion 2320. A second end of the sleeve 2316 includes an internal flange 2321 and a tapered portion 2322. An externally threaded connection 2324 of an end portion 2326 of a second tubular member 2328 having an annular recess 2330, is then positioned within the tubular sleeve 2316 and threadably coupled to the internally threaded connection 2312 of the end portion 2314 of the first tubular member 2310. The internal flange 2318 of the sleeve 2316 mates with and is received within the annular recess 2330.

[00182] The first tubular member 2310 includes a recess 2331. The internal flange 2321 mates with and is received within the annular recess 2331. Thus, the sleeve 2316 is coupled to and surrounds the external surfaces of the first and second tubular members 2310 and 2328.

[00183] The internally threaded connection 2312 of the end portion 2314 of the first tubular member 2310 is a box connection, and the externally threaded connection 2324 of the end portion 2326 of the second tubular member 2328 is a pin connection. In an exemplary embodiment, the internal diameter of the tubular sleeve 2316 is at least

approximately .020" greater than the outside diameters of the first and second tubular members 2310 and 2328. In this manner, during the threaded coupling of the first and second tubular members 2310 and 2328, fluidic materials within the first and second tubular members may be vented from the tubular members.

[00184] As illustrated in Fig. 23, the first and second tubular members 2310 and 2328, and the tubular sleeve 2316 may then be positioned within another structure 2332 such as, for example, a wellbore, and radially expanded and plastically deformed, for example, by displacing and/or rotating an expansion device 2334 through and/or within the interiors of the first and second tubular members. The tapered portions 2320 and 2322, of the tubular sleeve 2316 facilitates the insertion and movement of the first and second tubular members within and through the structure 2332, and the displacement of the expansion device 2334 through the interiors of the first and second tubular members 2310 and 2328, may be from top to bottom or from bottom to top.

[00185] During the radial expansion and plastic deformation of the first and second tubular members 2310 and 2328, the tubular sleeve 2316 is also radially expanded and plastically deformed. In an exemplary embodiment, as a result, the tubular sleeve 2316 may be maintained in circumferential tension and the end portions 2314 and 2326, of the first and second tubular members 2310 and 2328, may be maintained in circumferential compression.

[00186] Sleeve 2316 increases the axial tension loading of the connection between tubular members 2310 and 2328 before and after expansion by the expansion device 2334. Sleeve 2316 may be secured to tubular members 2310 and 2328 by a heat shrink fit.

[00187] In several exemplary embodiments, one or more portions of the first and second tubular members, 2310 and 2328, and the tubular sleeve 2316 have one or more of the material properties of one or more of the tubular members 12, 14, 24, 26, 102, 104, 106, 108, 202 and/or 204.

[00188] Referring to Fig. 24, in an exemplary embodiment, a first tubular member 2410 includes an internally threaded connection 2412 at an end portion 2414. A first end of a tubular sleeve 2416 includes an internal flange 2418 and a tapered portion 2420. A second end of the sleeve 2416 includes an internal flange 2421 and a tapered portion 2422. An externally threaded connection 2424 of an end portion 2426 of a second tubular member 2428 having an annular recess 2430, is then positioned within the tubular sleeve 2416 and threadably coupled to the internally threaded connection 2412 of the end portion 2414 of the first tubular member 2410. The internal flange 2418 of the sleeve 2416 mates with and is received within the annular recess 2430. The first tubular member 2410 includes a recess 2431. The internal flange 2421 mates with and is received within the annular recess 2431. Thus, the sleeve 2416 is coupled to and surrounds the external surfaces of the first and second tubular members 2410 and 2428.

[00189] The internally threaded connection 2412 of the end portion 2414 of the first tubular member 2410 is a box connection, and the externally threaded connection 2424 of the end portion 2426 of the second tubular member 2428 is a pin connection. In an exemplary embodiment, the internal diameter of the tubular sleeve 2416 is at least approximately .020" greater than the outside diameters of the first and second tubular members 2410 and 2428. In this manner, during the threaded coupling of the first and second tubular members 2410 and 2428, fluidic materials within the first and second tubular members may be vented from the tubular members.

[00190] As illustrated in Fig. 24, the first and second tubular members 2410 and 2428, and the tubular sleeve 2416 may then be positioned within another structure 2432 such as, for example, a wellbore, and radially expanded and plastically deformed, for example, by displacing and/or rotating an expansion device 2434 through and/or within the interiors of the first and second tubular members. The tapered portions 2420 and 2422, of the tubular sleeve 2416 facilitate the insertion and movement of the first and second tubular members within and through the structure 2432, and the displacement of the expansion device 2434 through the interiors of the first and second tubular members, 2410 and 2428, may be from top to bottom or from bottom to top.

[00191] During the radial expansion and plastic deformation of the first and second tubular members, 2410 and 2428, the tubular sleeve 2416 is also radially expanded and plastically deformed. In an exemplary embodiment, as a result, the tubular sleeve 2416 may be maintained in circumferential tension and the end portions, 2414 and 2426, of the first and second tubular members, 2410 and 2428, may be maintained in circumferential compression.

[00192] The sleeve 2416 increases the axial compression and tension loading of the connection between tubular members 2410 and 2428 before and after expansion by expansion device 2424. Sleeve 2416 may be secured to tubular members 2410 and 2428 by a heat shrink fit.

[00193] In several exemplary embodiments, one or more portions of the first and second tubular members, 2410 and 2428, and the tubular sleeve 2416 have one or more of the material properties of one or more of the tubular members 12, 14, 24, 26, 102, 104, 106, 108, 202 and/or 204.

[00194] Referring to Fig. 25, in an exemplary embodiment, a first tubular member 2510 includes an internally threaded connection 2512 at an end portion 2514. A first end of a tubular sleeve 2516 includes an internal flange 2518 and a relief 2520. A second end of the sleeve 2516 includes an internal flange 2521 and a relief 2522. An externally threaded connection 2524 of an end portion 2526 of a second tubular member 2528 having an annular recess 2530, is then positioned within the tubular sleeve 2516 and threadably

coupled to the internally threaded connection 2512 of the end portion 2514 of the first tubular member 2510. The internal flange 2518 of the sleeve 2516 mates with and is received within the annular recess 2530. The first tubular member 2510 includes a recess 2531. The internal flange 2521 mates with and is received within the annular recess 2531. Thus, the sleeve 2516 is coupled to and surrounds the external surfaces of the first and second tubular members 2510 and 2528.

[00195] The internally threaded connection 2512 of the end portion 2514 of the first tubular member 2510 is a box connection, and the externally threaded connection 2524 of the end portion 2526 of the second tubular member 2528 is a pin connection. In an exemplary embodiment, the internal diameter of the tubular sleeve 2516 is at least approximately .020" greater than the outside diameters of the first and second tubular members 2510 and 2528. In this manner, during the threaded coupling of the first and second tubular members 2510 and 2528, fluidic materials within the first and second tubular members may be vented from the tubular members.

[00196] As illustrated in Fig. 25, the first and second tubular members 2510 and 2528, and the tubular sleeve 2516 may then be positioned within another structure 2532 such as, for example, a wellbore, and radially expanded and plastically deformed, for example, by displacing and/or rotating an expansion device 2534 through and/or within the interiors of the first and second tubular members. The reliefs 2520 and 2522 are each filled with a sacrificial material 2540 including a tapered surface 2542 and 2544, respectively. The material 2540 may be a metal or a synthetic, and is provided to facilitate the insertion and movement of the first and second tubular members 2510 and 2528, through the structure 2532. The displacement of the expansion device 2534 through the interiors of the first and second tubular members 2510 and 2528, may, for example, be from top to bottom or from bottom to top.

[00197] During the radial expansion and plastic deformation of the first and second tubular members 2510 and 2528, the tubular sleeve 2516 is also radially expanded and plastically deformed. In an exemplary embodiment, as a result, the tubular sleeve 2516 may be maintained in circumferential tension and the end portions 2514 and 2526, of the first and second tubular members, 2510 and 2528, may be maintained in circumferential compression.

[00198] The addition of the sacrificial material 2540, provided on sleeve 2516, avoids stress risers on the sleeve 2516 and the tubular member 2510. The tapered surfaces 2542 and 2544 are intended to wear or even become damaged, thus incurring such wear or damage which would otherwise be borne by sleeve 2516. Sleeve 2516 may be secured to tubular members 2510 and 2528 by a heat shrink fit.

[00199] In several exemplary embodiments, one or more portions of the first and second tubular members, 2510 and 2528, and the tubular sleeve 2516 have one or more of the material properties of one or more of the tubular members 12, 14, 24, 26, 102, 104, 106, 108, 202 and/or 204.

[00200] Referring to Fig. 26, in an exemplary embodiment, a first tubular member 2610 includes an internally threaded connection 2612 at an end portion 2614. A first end of a tubular sleeve 2616 includes an internal flange 2618 and a tapered portion 2620. A second end of the sleeve 2616 includes an internal flange 2621 and a tapered portion 2622. An externally threaded connection 2624 of an end portion 2626 of a second tubular member 2628 having an annular recess 2630, is then positioned within the tubular sleeve 2616 and threadably coupled to the internally threaded connection 2612 of the end portion 2614 of the first tubular member 2610. The internal flange 2618 of the sleeve 2616 mates with and is received within the annular recess 2630.

[00201] The first tubular member 2610 includes a recess 2631. The internal flange 2621 mates with and is received within the annular recess 2631. Thus, the sleeve 2616 is coupled to and surrounds the external surfaces of the first and second tubular members 2610 and 2628.

[00202] The internally threaded connection 2612 of the end portion 2614 of the first tubular member 2610 is a box connection, and the externally threaded connection 2624 of the end portion 2626 of the second tubular member 2628 is a pin connection. In an exemplary embodiment, the internal diameter of the tubular sleeve 2616 is at least approximately .020" greater than the outside diameters of the first and second tubular members 2610 and 2628. In this manner, during the threaded coupling of the first and second tubular members 2610 and 2628, fluidic materials within the first and second tubular members may be vented from the tubular members.

[00203] As illustrated in Fig. 26, the first and second tubular members 2610 and 2628, and the tubular sleeve 2616 may then be positioned within another structure 2632 such as, for example, a wellbore, and radially expanded and plastically deformed, for example, by displacing and/or rotating an expansion device 2634 through and/or within the interiors of the first and second tubular members. The tapered portions 2620 and 2622, of the tubular sleeve 2616 facilitates the insertion and movement of the first and second tubular members within and through the structure 2632, and the displacement of the expansion device 2634 through the interiors of the first and second tubular members 2610 and 2628, may, for example, be from top to bottom or from bottom to top.

[00204] During the radial expansion and plastic deformation of the first and second tubular members 2610 and 2628, the tubular sleeve 2616 is also radially expanded and plastically deformed. In an exemplary embodiment, as a result, the tubular sleeve 2616 may

be maintained in circumferential tension and the end portions 2614 and 2626, of the first and second tubular members 2610 and 2628, may be maintained in circumferential compression.

[00205] Sleeve 2616 is covered by a thin walled cylinder of sacrificial material 2640. Spaces 2623 and 2624, adjacent tapered portions 2620 and 2622, respectively, are also filled with an excess of the sacrificial material 2640. The material may be a metal or a synthetic, and is provided to facilitate the insertion and movement of the first and second tubular members 2610 and 2628, through the structure 2632.

[00206] The addition of the sacrificial material 2640, provided on sleeve 2616, avoids stress risers on the sleeve 2616 and the tubular member 2610. The excess of the sacrificial material 2640 adjacent tapered portions 2620 and 2622 are intended to wear or even become damaged, thus incurring such wear or damage which would otherwise be borne by sleeve 2616. Sleeve 2616 may be secured to tubular members 2610 and 2628 by a heat shrink fit.

[00207] In several exemplary embodiments, one or more portions of the first and second tubular members, 2610 and 2628, and the tubular sleeve 2616 have one or more of the material properties of one or more of the tubular members 12, 14, 24, 26, 102, 104, 106, 108, 202 and/or 204.

[00208] Referring to Fig. 27, in an exemplary embodiment, a first tubular member 2710 includes an internally threaded connection 2712 at an end portion 2714. A first end of a tubular sleeve 2716 includes an internal flange 2718 and a tapered portion 2720. A second end of the sleeve 2716 includes an internal flange 2721 and a tapered portion 2722. An externally threaded connection 2724 of an end portion 2726 of a second tubular member 2728 having an annular recess 2730, is then positioned within the tubular sleeve 2716 and threadably coupled to the internally threaded connection 2712 of the end portion 2714 of the first tubular member 2710. The internal flange 2718 of the sleeve 2716 mates with and is received within the annular recess 2730.

[00209] The first tubular member 2710 includes a recess 2731. The internal flange 2721 mates with and is received within the annular recess 2731. Thus, the sleeve 2716 is coupled to and surrounds the external surfaces of the first and second tubular members 2710 and 2728.

[00210] The internally threaded connection 2712 of the end portion 2714 of the first tubular member 2710 is a box connection, and the externally threaded connection 2724 of the end portion 2726 of the second tubular member 2728 is a pin connection. In an exemplary embodiment, the internal diameter of the tubular sleeve 2716 is at least approximately .020" greater than the outside diameters of the first and second tubular members 2710 and 2728. In this manner, during the threaded coupling of the first and

second tubular members 2710 and 2728, fluidic materials within the first and second tubular members may be vented from the tubular members.

[00211] As illustrated in Fig. 27, the first and second tubular members 2710 and 2728, and the tubular sleeve 2716 may then be positioned within another structure 2732 such as, for example, a wellbore, and radially expanded and plastically deformed, for example, by displacing and/or rotating an expansion device 2734 through and/or within the interiors of the first and second tubular members. The tapered portions 2720 and 2722, of the tubular sleeve 2716 facilitates the insertion and movement of the first and second tubular members within and through the structure 2732, and the displacement of the expansion device 2734 through the interiors of the first and second tubular members 2710 and 2728, may be from top to bottom or from bottom to top.

[00212] During the radial expansion and plastic deformation of the first and second tubular members 2710 and 2728, the tubular sleeve 2716 is also radially expanded and plastically deformed. In an exemplary embodiment, as a result, the tubular sleeve 2716 may be maintained in circumferential tension and the end portions 2714 and 2726, of the first and second tubular members 2710 and 2728, may be maintained in circumferential compression.

[00213] Sleeve 2716 has a variable thickness due to one or more reduced thickness portions 2790 and/or increased thickness portions 2792.

[00214] Varying the thickness of sleeve 2716 provides the ability to control or induce stresses at selected positions along the length of sleeve 2716 and the end portions 2724 and 2726. Sleeve 2716 may be secured to tubular members 2710 and 2728 by a heat shrink fit.

[00215] In several exemplary embodiments, one or more portions of the first and second tubular members, 2710 and 2728, and the tubular sleeve 2716 have one or more of the material properties of one or more of the tubular members 12, 14, 24, 26, 102, 104, 106, 108, 202 and/or 204.

[00216] Referring to Fig. 28, in an alternative embodiment, instead of varying the thickness of sleeve 2716, the same result described above with reference to Fig. 27, may be achieved by adding a member 2740 which may be coiled onto the grooves 2739 formed in sleeve 2716, thus varying the thickness along the length of sleeve 2716.

[00217] Referring to Fig. 29, in an exemplary embodiment, a first tubular member 2910 includes an internally threaded connection 2912 and an internal annular recess 2914 at an end portion 2916. A first end of a tubular sleeve 2918 includes an internal flange 2920, and a second end of the sleeve 2916 mates with and receives the end portion 2916 of the first tubular member 2910. An externally threaded connection 2922 of an end portion 2924 of a second tubular member 2926 having an annular recess 2928, is then positioned within the tubular sleeve 2918 and threadably coupled to the internally threaded connection 2912

of the end portion 2916 of the first tubular member 2910. The internal flange 2920 of the sleeve 2918 mates with and is received within the annular recess 2928. A sealing element 2930 is received within the internal annular recess 2914 of the end portion 2916 of the first tubular member 2910.

[00218] The internally threaded connection 2912 of the end portion 2916 of the first tubular member 2910 is a box connection, and the externally threaded connection 2922 of the end portion 2924 of the second tubular member 2926 is a pin connection. In an exemplary embodiment, the internal diameter of the tubular sleeve 2918 is at least approximately .020" greater than the outside diameters of the first tubular member 2910. In this manner, during the threaded coupling of the first and second tubular members 2910 and 2926, fluidic materials within the first and second tubular members may be vented from the tubular members.

[00219] The first and second tubular members 2910 and 2926, and the tubular sleeve 2918 may be positioned within another structure such as, for example, a wellbore, and radially expanded and plastically deformed, for example, by displacing and/or rotating an expansion device through and/or within the interiors of the first and second tubular members.

[00220] During the radial expansion and plastic deformation of the first and second tubular members 2910 and 2926, the tubular sleeve 2918 is also radially expanded and plastically deformed. In an exemplary embodiment, as a result, the tubular sleeve 2918 may be maintained in circumferential tension and the end portions 2916 and 2924, of the first and second tubular members 2910 and 2926, respectively, may be maintained in circumferential compression.

[00221] In an exemplary embodiment, before, during, and after the radial expansion and plastic deformation of the first and second tubular members 2910 and 2926, and the tubular sleeve 2918, the sealing element 2930 seals the interface between the first and second tubular members. In an exemplary embodiment, during and after the radial expansion and plastic deformation of the first and second tubular members 2910 and 2926, and the tubular sleeve 2918, a metal to metal seal is formed between at least one of: the first and second tubular members 2910 and 2926, the first tubular member and the tubular sleeve 2918, and/or the second tubular member and the tubular sleeve. In an exemplary embodiment, the metal to metal seal is both fluid tight and gas tight.

[00222] In several exemplary embodiments, one or more portions of the first and second tubular members, 2910 and 2926, the tubular sleeve 2918, and the sealing element 2930 have one or more of the material properties of one or more of the tubular members 12, 14, 24, 26, 102, 104, 106, 108, 202 and/or 204.

[00223] Referring to Fig. 30a, in an exemplary embodiment, a first tubular member 3010 includes internally threaded connections 3012a and 3012b, spaced apart by a

cylindrical internal surface 3014, at an end portion 3016. Externally threaded connections 3018a and 3018b, spaced apart by a cylindrical external surface 3020, of an end portion 3022 of a second tubular member 3024 are threadably coupled to the internally threaded connections, 3012a and 3012b, respectively, of the end portion 3016 of the first tubular member 3010. A sealing element 3026 is received within an annulus defined between the internal cylindrical surface 3014 of the first tubular member 3010 and the external cylindrical surface 3020 of the second tubular member 3024.

[00224] The internally threaded connections, 3012a and 3012b, of the end portion 3016 of the first tubular member 3010 are box connections, and the externally threaded connections, 3018a and 3018b, of the end portion 3022 of the second tubular member 3024 are pin connections. In an exemplary embodiment, the sealing element 3026 is an elastomeric and/or metallic sealing element.

[00225] The first and second tubular members 3010 and 3024 may be positioned within another structure such as, for example, a wellbore, and radially expanded and plastically deformed, for example, by displacing and/or rotating an expansion device through and/or within the interiors of the first and second tubular members.

[00226] In an exemplary embodiment, before, during, and after the radial expansion and plastic deformation of the first and second tubular members 3010 and 3024, the sealing element 3026 seals the interface between the first and second tubular members. In an exemplary embodiment, before, during and/or after the radial expansion and plastic deformation of the first and second tubular members 3010 and 3024, a metal to metal seal is formed between at least one of: the first and second tubular members 3010 and 3024, the first tubular member and the sealing element 3026, and/or the second tubular member and the sealing element. In an exemplary embodiment, the metal to metal seal is both fluid tight and gas tight.

[00227] In an alternative embodiment, the sealing element 3026 is omitted, and during and/or after the radial expansion and plastic deformation of the first and second tubular members 3010 and 3024, a metal to metal seal is formed between the first and second tubular members.

[00228] In several exemplary embodiments, one or more portions of the first and second tubular members, 3010 and 3024, the sealing element 3026 have one or more of the material properties of one or more of the tubular members 12, 14, 24, 26, 102, 104, 106, 108, 202 and/or 204.

[00229] Referring to Fig. 30b, in an exemplary embodiment, a first tubular member 3030 includes internally threaded connections 3032a and 3032b, spaced apart by an undulating approximately cylindrical internal surface 3034, at an end portion 3036. Externally threaded connections 3038a and 3038b, spaced apart by a cylindrical external

surface 3040, of an end portion 3042 of a second tubular member 3044 are threadably coupled to the internally threaded connections, 3032a and 3032b, respectively, of the end portion 3036 of the first tubular member 3030. A sealing element 3046 is received within an annulus defined between the undulating approximately cylindrical internal surface 3034 of the first tubular member 3030 and the external cylindrical surface 3040 of the second tubular member 3044.

[00230] The internally threaded connections, 3032a and 3032b, of the end portion 3036 of the first tubular member 3030 are box connections, and the externally threaded connections, 3038a and 3038b, of the end portion 3042 of the second tubular member 3044 are pin connections. In an exemplary embodiment, the sealing element 3046 is an elastomeric and/or metallic sealing element.

[00231] The first and second tubular members 3030 and 3044 may be positioned within another structure such as, for example, a wellbore, and radially expanded and plastically deformed, for example, by displacing and/or rotating an expansion device through and/or within the interiors of the first and second tubular members.

[00232] In an exemplary embodiment, before, during, and after the radial expansion and plastic deformation of the first and second tubular members 3030 and 3044, the sealing element 3046 seals the interface between the first and second tubular members. In an exemplary embodiment, before, during and/or after the radial expansion and plastic deformation of the first and second tubular members 3030 and 3044, a metal to metal seal is formed between at least one of: the first and second tubular members 3030 and 3044, the first tubular member and the sealing element 3046, and/or the second tubular member and the sealing element. In an exemplary embodiment, the metal to metal seal is both fluid tight and gas tight.

[00233] In an alternative embodiment, the sealing element 3046 is omitted, and during and/or after the radial expansion and plastic deformation of the first and second tubular members 3030 and 3044, a metal to metal seal is formed between the first and second tubular members.

[00234] In several exemplary embodiments, one or more portions of the first and second tubular members, 3030 and 3044, the sealing element 3046 have one or more of the material properties of one or more of the tubular members 12, 14, 24, 26, 102, 104, 106, 108, 202 and/or 204.

[00235] Referring to Fig. 30c, in an exemplary embodiment, a first tubular member 3050 includes internally threaded connections 3052a and 3052b, spaced apart by a cylindrical internal surface 3054 including one or more square grooves 3056, at an end portion 3058. Externally threaded connections 3060a and 3060b, spaced apart by a cylindrical external surface 3062 including one or more square grooves 3064, of an end

portion 3066 of a second tubular member 3068 are threadably coupled to the internally threaded connections, 3052a and 3052b, respectively, of the end portion 3058 of the first tubular member 3050. A sealing element 3070 is received within an annulus defined between the cylindrical internal surface 3054 of the first tubular member 3050 and the external cylindrical surface 3062 of the second tubular member 3068.

[00236] The internally threaded connections, 3052a and 3052b, of the end portion 3058 of the first tubular member 3050 are box connections, and the externally threaded connections, 3060a and 3060b, of the end portion 3066 of the second tubular member 3068 are pin connections. In an exemplary embodiment, the sealing element 3070 is an elastomeric and/or metallic sealing element.

[00237] The first and second tubular members 3050 and 3068 may be positioned within another structure such as, for example, a wellbore, and radially expanded and plastically deformed, for example, by displacing and/or rotating an expansion device through and/or within the interiors of the first and second tubular members.

[00238] In an exemplary embodiment, before, during, and after the radial expansion and plastic deformation of the first and second tubular members 3050 and 3068, the sealing element 3070 seals the interface between the first and second tubular members. In an exemplary embodiment, before, during and/or after the radial expansion and plastic deformation of the first and second tubular members, 3050 and 3068, a metal to metal seal is formed between at least one of: the first and second tubular members, the first tubular member and the sealing element 3070, and/or the second tubular member and the sealing element. In an exemplary embodiment, the metal to metal seal is both fluid tight and gas tight.

[00239] In an alternative embodiment, the sealing element 3070 is omitted, and during and/or after the radial expansion and plastic deformation of the first and second tubular members 950 and 968, a metal to metal seal is formed between the first and second tubular members.

[00240] In several exemplary embodiments, one or more portions of the first and second tubular members, 3050 and 3068, the sealing element 3070 have one or more of the material properties of one or more of the tubular members 12, 14, 24, 26, 102, 104, 106, 108, 202 and/or 204.

[00241] Referring to Fig. 31, in an exemplary embodiment, a first tubular member 3110 includes internally threaded connections, 3112a and 3112b, spaced apart by a non-threaded internal surface 3114, at an end portion 3116. Externally threaded connections, 3118a and 3118b, spaced apart by a non-threaded external surface 3120, of an end portion 3122 of a second tubular member 3124 are threadably coupled to the internally threaded

connections, 3112a and 3112b, respectively, of the end portion 3122 of the first tubular member 3124.

[00242] First, second, and/or third tubular sleeves, 3126, 3128, and 3130, are coupled the external surface of the first tubular member 3110 in opposing relation to the threaded connection formed by the internal and external threads, 3112a and 3118a, the interface between the non-threaded surfaces, 3114 and 3120, and the threaded connection formed by the internal and external threads, 3112b and 3118b, respectively.

[00243] The internally threaded connections, 3112a and 3112b, of the end portion 3116 of the first tubular member 3110 are box connections, and the externally threaded connections, 3118a and 3118b, of the end portion 3122 of the second tubular member 3124 are pin connections.

[00244] The first and second tubular members 3110 and 3124, and the tubular sleeves 3126, 3128, and/or 3130, may then be positioned within another structure 3132 such as, for example, a wellbore, and radially expanded and plastically deformed, for example, by displacing and/or rotating an expansion device 3134 through and/or within the interiors of the first and second tubular members.

[00245] During the radial expansion and plastic deformation of the first and second tubular members 3110 and 3124, the tubular sleeves 3126, 3128 and/or 3130 are also radially expanded and plastically deformed. In an exemplary embodiment, as a result, the tubular sleeves 3126, 3128, and/or 3130 are maintained in circumferential tension and the end portions 3116 and 3122, of the first and second tubular members 3110 and 3124, may be maintained in circumferential compression.

[00246] The sleeves 3126, 3128, and/or 3130 may, for example, be secured to the first tubular member 3110 by a heat shrink fit.

[00247] In several exemplary embodiments, one or more portions of the first and second tubular members, 3110 and 3124, and the sleeves, 3126, 3128, and 3130, have one or more of the material properties of one or more of the tubular members 12, 14, 24, 26, 102, 104, 106, 108, 202 and/or 204.

[00248] Referring to Fig. 32a, in an exemplary embodiment, a first tubular member 3210 includes an internally threaded connection 3212 at an end portion 3214. An externally threaded connection 3216 of an end portion 3218 of a second tubular member 3220 are threadably coupled to the internally threaded connection 3212 of the end portion 3214 of the first tubular member 3210.

[00249] The internally threaded connection 3212 of the end portion 3214 of the first tubular member 3210 is a box connection, and the externally threaded connection 3216 of the end portion 3218 of the second tubular member 3220 is a pin connection.

[00250] A tubular sleeve 3222 including internal flanges 3224 and 3226 is positioned proximate and surrounding the end portion 3214 of the first tubular member 3210. As illustrated in Fig. 32b, the tubular sleeve 3222 is then forced into engagement with the external surface of the end portion 3214 of the first tubular member 3210 in a conventional manner. As a result, the end portions, 3214 and 3218, of the first and second tubular members, 3210 and 3220, are upset in an undulating fashion.

[00251] The first and second tubular members 3210 and 3220, and the tubular sleeve 3222, may then be positioned within another structure such as, for example, a wellbore, and radially expanded and plastically deformed, for example, by displacing and/or rotating an expansion device through and/or within the interiors of the first and second tubular members.

[00252] During the radial expansion and plastic deformation of the first and second tubular members 3210 and 3220, the tubular sleeve 3222 is also radially expanded and plastically deformed. In an exemplary embodiment, as a result, the tubular sleeve 3222 is maintained in circumferential tension and the end portions 3214 and 3218, of the first and second tubular members 3210 and 3220, may be maintained in circumferential compression.

[00253] In several exemplary embodiments, one or more portions of the first and second tubular members, 3210 and 3220, and the sleeve 3222 have one or more of the material properties of one or more of the tubular members 12, 14, 24, 26, 102, 104, 106, 108, 202 and/or 204.

[00254] Referring to Fig. 33, in an exemplary embodiment, a first tubular member 3310 includes an internally threaded connection 3312 and an annular projection 3314 at an end portion 3316.

[00255] A first end of a tubular sleeve 3318 that includes an internal flange 3320 having a tapered portion 3322 and an annular recess 3324 for receiving the annular projection 3314 of the first tubular member 3310, and a second end that includes a tapered portion 3326, is then mounted upon and receives the end portion 3316 of the first tubular member 3310.

[00256] In an exemplary embodiment, the end portion 3316 of the first tubular member 3310 abuts one side of the internal flange 3320 of the tubular sleeve 3318 and the annular projection 3314 of the end portion of the first tubular member mates with and is received within the annular recess 3324 of the internal flange of the tubular sleeve, and the internal diameter of the internal flange 3320 of the tubular sleeve 3318 is substantially equal to or greater than the maximum internal diameter of the internally threaded connection 3312 of the end portion 3316 of the first tubular member 3310. An externally threaded connection 3326 of an end portion 3328 of a second tubular member 3330 having an annular recess 3332 is then positioned within the tubular sleeve 3318 and threadably coupled to the internally threaded connection 3312 of the end portion 3316 of the first tubular member

3310. In an exemplary embodiment, the internal flange 3332 of the tubular sleeve 3318 mates with and is received within the annular recess 3332 of the end portion 3328 of the second tubular member 3330. Thus, the tubular sleeve 3318 is coupled to and surrounds the external surfaces of the first and second tubular members, 3310 and 3328.

[00257] The internally threaded connection 3312 of the end portion 3316 of the first tubular member 3310 is a box connection, and the externally threaded connection 3326 of the end portion 3328 of the second tubular member 3330 is a pin connection. In an exemplary embodiment, the internal diameter of the tubular sleeve 3318 is at least approximately .020" greater than the outside diameters of the first and second tubular members, 3310 and 3330. In this manner, during the threaded coupling of the first and second tubular members, 3310 and 3330, fluidic materials within the first and second tubular members may be vented from the tubular members.

[00258] As illustrated in Fig. 33, the first and second tubular members, 3310 and 3330, and the tubular sleeve 3318 may be positioned within another structure 3334 such as, for example, a cased or uncased wellbore, and radially expanded and plastically deformed, for example, by displacing and/or rotating a conventional expansion device 3336 within and/or through the interiors of the first and second tubular members. The tapered portions, 3322 and 3326, of the tubular sleeve 3318 facilitate the insertion and movement of the first and second tubular members within and through the structure 3334, and the movement of the expansion device 3336 through the interiors of the first and second tubular members, 3310 and 3330, may, for example, be from top to bottom or from bottom to top.

[00259] During the radial expansion and plastic deformation of the first and second tubular members, 3310 and 3330, the tubular sleeve 3318 is also radially expanded and plastically deformed. As a result, the tubular sleeve 3318 may be maintained in circumferential tension and the end portions, 3316 and 3328, of the first and second tubular members, 3310 and 3330, may be maintained in circumferential compression.

[00260] Sleeve 3316 increases the axial compression loading of the connection between tubular members 3310 and 3330 before and after expansion by the expansion device 3336. Sleeve 3316 may be secured to tubular members 3310 and 3330, for example, by a heat shrink fit.

[00261] In several alternative embodiments, the first and second tubular members, 3310 and 3330, are radially expanded and plastically deformed using other conventional methods for radially expanding and plastically deforming tubular members such as, for example, internal pressurization, hydroforming, and/or roller expansion devices and/or any one or combination of the conventional commercially available expansion products and services available from Baker Hughes, Weatherford International, and/or Enventure Global Technology L.L.C.

[00262] The use of the tubular sleeve 3318 during (a) the coupling of the first tubular member 3310 to the second tubular member 3330, (b) the placement of the first and second tubular members in the structure 3334, and (c) the radial expansion and plastic deformation of the first and second tubular members provides a number of significant benefits. For example, the tubular sleeve 3318 protects the exterior surfaces of the end portions, 3316 and 3328, of the first and second tubular members, 3310 and 3330, during handling and insertion of the tubular members within the structure 3334. In this manner, damage to the exterior surfaces of the end portions, 3316 and 3328, of the first and second tubular members, 3310 and 3330, is avoided that could otherwise result in stress concentrations that could cause a catastrophic failure during subsequent radial expansion operations. Furthermore, the tubular sleeve 3318 provides an alignment guide that facilitates the insertion and threaded coupling of the second tubular member 3330 to the first tubular member 3310. In this manner, misalignment that could result in damage to the threaded connections, 3312 and 3326, of the first and second tubular members, 3310 and 3330, may be avoided. In addition, during the relative rotation of the second tubular member with respect to the first tubular member, required during the threaded coupling of the first and second tubular members, the tubular sleeve 3318 provides an indication of to what degree the first and second tubular members are threadably coupled. For example, if the tubular sleeve 3318 can be easily rotated, that would indicate that the first and second tubular members, 3310 and 3330, are not fully threadably coupled and in intimate contact with the internal flange 3320 of the tubular sleeve. Furthermore, the tubular sleeve 3318 may prevent crack propagation during the radial expansion and plastic deformation of the first and second tubular members, 3310 and 3330. In this manner, failure modes such as, for example, longitudinal cracks in the end portions, 3316 and 3328, of the first and second tubular members may be limited in severity or eliminated all together. In addition, after completing the radial expansion and plastic deformation of the first and second tubular members, 3310 and 3330, the tubular sleeve 3318 may provide a fluid tight metal-to-metal seal between interior surface of the tubular sleeve 3318 and the exterior surfaces of the end portions, 3316 and 3328, of the first and second tubular members. In this manner, fluidic materials are prevented from passing through the threaded connections, 3312 and 3326, of the first and second tubular members, 3310 and 3330, into the annulus between the first and second tubular members and the structure 3334. Furthermore, because, following the radial expansion and plastic deformation of the first and second tubular members, 3310 and 3330, the tubular sleeve 3318 may be maintained in circumferential tension and the end portions, 3316 and 3328, of the first and second tubular members, 3310 and 3330, may be maintained in circumferential compression, axial loads and/or torque loads may be transmitted through the tubular sleeve.

[00263] In several exemplary embodiments, one or more portions of the first and second tubular members, 3310 and 3330, and the sleeve 3318 have one or more of the material properties of one or more of the tubular members 12, 14, 24, 26, 102, 104, 106, 108, 202 and/or 204.

[00264] Referring to Figs. 34a, 34b, and 34c, in an exemplary embodiment, a first tubular member 3410 includes an internally threaded connection 1312 and one or more external grooves 3414 at an end portion 3416.

[00265] A first end of a tubular sleeve 3418 that includes an internal flange 3420 and a tapered portion 3422, a second end that includes a tapered portion 3424, and an intermediate portion that includes one or more longitudinally aligned openings 3426, is then mounted upon and receives the end portion 3416 of the first tubular member 3410.

[00266] In an exemplary embodiment, the end portion 3416 of the first tubular member 3410 abuts one side of the internal flange 3420 of the tubular sleeve 3418, and the internal diameter of the internal flange 3420 of the tubular sleeve 3416 is substantially equal to or greater than the maximum internal diameter of the internally threaded connection 3412 of the end portion 3416 of the first tubular member 3410. An externally threaded connection 3428 of an end portion 3430 of a second tubular member 3432 that includes one or more internal grooves 3434 is then positioned within the tubular sleeve 3418 and threadably coupled to the internally threaded connection 3412 of the end portion 3416 of the first tubular member 3410. In an exemplary embodiment, the internal flange 3420 of the tubular sleeve 3418 mates with and is received within an annular recess 3436 defined in the end portion 3430 of the second tubular member 3432. Thus, the tubular sleeve 3418 is coupled to and surrounds the external surfaces of the first and second tubular members, 3410 and 3432.

[00267] The first and second tubular members, 3410 and 3432, and the tubular sleeve 3418 may be positioned within another structure such as, for example, a cased or uncased wellbore, and radially expanded and plastically deformed, for example, by displacing and/or rotating a conventional expansion device within and/or through the interiors of the first and second tubular members. The tapered portions, 3422 and 3424, of the tubular sleeve 3418 facilitate the insertion and movement of the first and second tubular members within and through the structure, and the movement of the expansion device through the interiors of the first and second tubular members, 3410 and 3432, may be from top to bottom or from bottom to top.

[00268] During the radial expansion and plastic deformation of the first and second tubular members, 3410 and 3432, the tubular sleeve 3418 is also radially expanded and plastically deformed. As a result, the tubular sleeve 3418 may be maintained in circumferential tension and the end portions, 3416 and 3430, of the first and second tubular members, 3410 and 3432, may be maintained in circumferential compression.

[00269] Sleeve 3416 increases the axial compression loading of the connection between tubular members 3410 and 3432 before and after expansion by the expansion device. The sleeve 3418 may be secured to tubular members 3410 and 3432, for example, by a heat shrink fit.

[00270] During the radial expansion and plastic deformation of the first and second tubular members, 3410 and 3432, the grooves 3414 and/or 3434 and/or the openings 3426 provide stress concentrations that in turn apply added stress forces to the mating threads of the threaded connections, 3412 and 3428. As a result, during and after the radial expansion and plastic deformation of the first and second tubular members, 3410 and 3432, the mating threads of the threaded connections, 3412 and 3428, are maintained in metal to metal contact thereby providing a fluid and gas tight connection. In an exemplary embodiment, the orientations of the grooves 3414 and/or 3434 and the openings 3426 are orthogonal to one another. In an exemplary embodiment, the grooves 3414 and/or 3434 are helical grooves.

[00271] In several alternative embodiments, the first and second tubular members, 3410 and 3432, are radially expanded and plastically deformed using other conventional methods for radially expanding and plastically deforming tubular members such as, for example, internal pressurization, hydroforming, and/or roller expansion devices and/or any one or combination of the conventional commercially available expansion products and services available from Baker Hughes, Weatherford International, and/or Enventure Global Technology L.L.C.

[00272] The use of the tubular sleeve 3418 during (a) the coupling of the first tubular member 3410 to the second tubular member 3432, (b) the placement of the first and second tubular members in the structure, and (c) the radial expansion and plastic deformation of the first and second tubular members provides a number of significant benefits. For example, the tubular sleeve 3418 protects the exterior surfaces of the end portions, 3416 and 3430, of the first and second tubular members, 3410 and 3432, during handling and insertion of the tubular members within the structure. In this manner, damage to the exterior surfaces of the end portions, 3416 and 3430, of the first and second tubular members, 3410 and 3432, is avoided that could otherwise result in stress concentrations that could cause a catastrophic failure during subsequent radial expansion operations. Furthermore, the tubular sleeve 3418 provides an alignment guide that facilitates the insertion and threaded coupling of the second tubular member 3432 to the first tubular member 3410. In this manner, misalignment that could result in damage to the threaded connections, 3412 and 3428, of the first and second tubular members, 3410 and 3432, may be avoided. In addition, during the relative rotation of the second tubular member with respect to the first tubular member, required during the threaded coupling of the first and second tubular members, the tubular sleeve 3416 provides an indication of to what degree the first and second tubular members

are threadably coupled. For example, if the tubular sleeve 3418 can be easily rotated, that would indicate that the first and second tubular members, 3410 and 3432, are not fully threadably coupled and in intimate contact with the internal flange 3420 of the tubular sleeve. Furthermore, the tubular sleeve 3418 may prevent crack propagation during the radial expansion and plastic deformation of the first and second tubular members, 3410 and 3432. In this manner, failure modes such as, for example, longitudinal cracks in the end portions, 3416 and 3430, of the first and second tubular members may be limited in severity or eliminated all together. In addition, after completing the radial expansion and plastic deformation of the first and second tubular members, 3410 and 3432, the tubular sleeve 3418 may provide a fluid and gas tight metal-to-metal seal between interior surface of the tubular sleeve 3418 and the exterior surfaces of the end portions, 3416 and 3430, of the first and second tubular members. In this manner, fluidic materials are prevented from passing through the threaded connections, 3412 and 3430, of the first and second tubular members, 3410 and 3432, into the annulus between the first and second tubular members and the structure. Furthermore, because, following the radial expansion and plastic deformation of the first and second tubular members, 3410 and 3432, the tubular sleeve 3418 may be maintained in circumferential tension and the end portions, 3416 and 3430, of the first and second tubular members, 3410 and 3432, may be maintained in circumferential compression, axial loads and/or torque loads may be transmitted through the tubular sleeve.

[00273] In several exemplary embodiments, the first and second tubular members described above with reference to Figs. 1 to 34c are radially expanded and plastically deformed using the expansion device in a conventional manner and/or using one or more of the methods and apparatus disclosed in one or more of the following: The present application is related to the following: (1) U.S. patent application serial no. 09/454,139, attorney docket no. 25791.03.02, filed on 12/3/1999, (2) U.S. patent application serial no. 09/510,913, attorney docket no. 25791.7.02, filed on 2/23/2000, (3) U.S. patent application serial no. 09/502,350, attorney docket no. 25791.8.02, filed on 2/10/2000, (4) U.S. patent application serial no. 09/440,338, attorney docket no. 25791.9.02, filed on 11/15/1999, (5) U.S. patent application serial no. 09/523,460, attorney docket no. 25791.11.02, filed on 3/10/2000, (6) U.S. patent application serial no. 09/512,895, attorney docket no. 25791.12.02, filed on 2/24/2000, (7) U.S. patent application serial no. 09/511,941, attorney docket no. 25791.16.02, filed on 2/24/2000, (8) U.S. patent application serial no. 09/588,946, attorney docket no. 25791.17.02, filed on 6/7/2000, (9) U.S. patent application serial no. 09/559,122, attorney docket no. 25791.23.02, filed on 4/26/2000, (10) PCT patent application serial no. PCT/US00/18635, attorney docket no. 25791.25.02, filed on 7/9/2000, (11) U.S. provisional patent application serial no. 60/162,671, attorney docket no. 25791.27, filed on 11/1/1999, (12) U.S. provisional patent application serial no. 60/154,047, attorney

docket no. 25791.29, filed on 9/16/1999, (13) U.S. provisional patent application serial no. 60/159,082, attorney docket no. 25791.34, filed on 10/12/1999, (14) U.S. provisional patent application serial no. 60/159,039, attorney docket no. 25791.36, filed on 10/12/1999, (15) U.S. provisional patent application serial no. 60/159,033, attorney docket no. 25791.37, filed on 10/12/1999, (16) U.S. provisional patent application serial no. 60/212,359, attorney docket no. 25791.38, filed on 6/19/2000, (17) U.S. provisional patent application serial no. 60/165,228, attorney docket no. 25791.39, filed on 11/12/1999, (18) U.S. provisional patent application serial no. 60/221,443, attorney docket no. 25791.45, filed on 7/28/2000, (19) U.S. provisional patent application serial no. 60/221,645, attorney docket no. 25791.46, filed on 7/28/2000, (20) U.S. provisional patent application serial no. 60/233,638, attorney docket no. 25791.47, filed on 9/18/2000, (21) U.S. provisional patent application serial no. 60/237,334, attorney docket no. 25791.48, filed on 10/2/2000, (22) U.S. provisional patent application serial no. 60/270,007, attorney docket no. 25791.50, filed on 2/20/2001, (23) U.S. provisional patent application serial no. 60/262,434, attorney docket no. 25791.51, filed on 1/17/2001, (24) U.S, provisional patent application serial no. 60/259,486, attorney docket no. 25791.52, filed on 1/3/2001, (25) U.S. provisional patent application serial no. 60/303,740, attorney docket no. 25791.61, filed on 7/6/2001, (26) U.S. provisional patent application serial no. 60/313,453, attorney docket no. 25791.59, filed on 8/20/2001, (27) U.S. provisional patent application serial no. 60/317,985, attorney docket no. 25791.67, filed on 9/6/2001, (28) U.S. provisional patent application serial no. 60/3318,386, attorney docket no. 25791.67.02, filed on 9/10/2001, (29) U.S. utility patent application serial no. 09/969,922, attorney docket no. 25791.69, filed on 10/3/2001, (30) U.S. utility patent application serial no. 10/016,467, attorney docket no. 25791.70, filed on December 10, 2001, (31) U.S. provisional patent application serial no. 60/343,674, attorney docket no. 25791.68, filed on 12/27/2001; and (32) U.S. provisional patent application serial no. 60/346,309, attorney docket no. 25791.92, filed on 01/07/02, the disclosures of which are incorporated herein by reference.

[00274] Referring to Fig. 35a an exemplary embodiment of an expandable tubular member 3500 includes a first tubular region 3502 and a second tubular portion 3504. In an exemplary embodiment, the material properties of the first and second tubular regions, 3502 and 3504, are different. In an exemplary embodiment, the yield points of the first and second tubular regions, 3502 and 3504, are different. In an exemplary embodiment, the yield point of the first tubular region 3502 is less than the yield point of the second tubular region 3504. In several exemplary embodiments, one or more of the expandable tubular members, 12, 14, 24, 26, 102, 104, 106, 108, 202 and/or 204 incorporate the tubular member 3500.

[00275] Referring to Fig. 35b, in an exemplary embodiment, the yield point within the first and second tubular regions, 3502a and 3502b, of the expandable tubular member 3502

vary as a function of the radial position within the expandable tubular member. In an exemplary embodiment, the yield point increases as a function of the radial position within the expandable tubular member 3502. In an exemplary embodiment, the relationship between the yield point and the radial position within the expandable tubular member 3502 is a linear relationship. In an exemplary embodiment, the relationship between the yield point and the radial position within the expandable tubular member 3502 is a non-linear relationship. In an exemplary embodiment, the yield point increases at different rates within the first and second tubular regions, 3502a and 3502b, as a function of the radial position within the expandable tubular member 3502. In an exemplary embodiment, the functional relationship, and value, of the yield points within the first and second tubular regions, 3502a and 3502b, of the expandable tubular member 3502 are modified by the radial expansion and plastic deformation of the expandable tubular member.

[00276] In several exemplary embodiments, one or more of the expandable tubular members, 12, 14, 24, 26, 102, 104, 106, 108, 202, 204 and/or 3502, prior to a radial expansion and plastic deformation, include a microstructure that is a combination of a hard phase, such as martensite, a soft phase, such as ferrite, and a transitionary phase, such as retained austentite. In this manner, the hard phase provides high strength, the soft phase provides ductility, and the transitionary phase transitions to a hard phase, such as martensite, during a radial expansion and plastic deformation. Furthermore, in this manner, the yield point of the tubular member increases as a result of the radial expansion and plastic deformation. Further, in this manner, the tubular member is ductile, prior to the radial expansion and plastic deformation, thereby facilitating the radial expansion and plastic deformation. In an exemplary embodiment, the composition of a dual-phase expandable tubular member includes (weight percentages): about 0.1% C, 1.2% Mn, and 0.3% Si.

[00277] In an exemplary experimental embodiment, as illustrated in Figs. 36a-36c, one or more of the expandable tubular members, 12, 14, 24, 26, 102, 104, 106, 108, 202, 204 and/or 3502 are processed in accordance with a method 3600, in which, in step 3602, an expandable tubular member 3602a is provided that is a steel alloy having following material composition (by weight percentage): 0.065% C, 1.44% Mn, 0.01% P, 0.002% S, 0.24% Si, 0.01% Cu, 0.01% Ni, 0.02% Cr, 0.05% V, 0.01%Mo, 0.01% Nb, and 0.01% Ti. In an exemplary experimental embodiment, the expandable tubular member 3602a provided in step 3602 has a yield strength of 45 ksi, and a tensile strength of 69 ksi.

[00278] In an exemplary experimental embodiment, as illustrated in Fig. 36b, in step 3602, the expandable tubular member 3602a includes a microstructure that includes martensite, pearlite, and V, Ni, and/or Ti carbides.

[00279] In an exemplary embodiment, the expandable tubular member 3602a is then heated at a temperature of 790 °C for about 10 minutes in step 3604.

[00280] In an exemplary embodiment, the expandable tubular member 3602a is then quenched in water in step 3606.

[00281] In an exemplary experimental embodiment, as illustrated in Fig. 36c, following the completion of step 3606, the expandable tubular member 3602a includes a microstructure that includes new ferrite, grain pearlite, martensite, and ferrite. In an exemplary experimental embodiment, following the completion of step 3606, the expandable tubular member 3602a has a yield strength of 67 ksi, and a tensile strength of 95 ksi.

[00282] In an exemplary embodiment, the expandable tubular member 3602a is then radially expanded and plastically deformed using one or more of the methods and apparatus described above. In an exemplary embodiment, following the radial expansion and plastic deformation of the expandable tubular member 3602a, the yield strength of the expandable tubular member is about 95 ksi.

[00283] In an exemplary experimental embodiment, as illustrated in Figs. 37a-37c, one or more of the expandable tubular members, 12, 14, 24, 26, 102, 104, 106, 108, 202, 204 and/or 3502 are processed in accordance with a method 3700, in which, in step 3702, an expandable tubular member 3702a is provided that is a steel alloy having following material composition (by weight percentage): 0.18% C, 1.28% Mn, 0.017% P, 0.004% S, 0.29% Si, 0.01% Cu, 0.01% Ni, 0.03% Cr, 0.04% V, 0.01%Mo, 0.03% Nb, and 0.01% Ti. In an exemplary experimental embodiment, the expandable tubular member 3702a provided in step 3702 has a yield strength of 60 ksi, and a tensile strength of 80 ksi.

[00284] In an exemplary experimental embodiment, as illustrated in Fig. 37b, in step 3702, the expandable tubular member 3702a includes a microstructure that includes pearlite and pearlite striation.

[00285] In an exemplary embodiment, the expandable tubular member 3702a is then heated at a temperature of 790 °C for about 10 minutes in step 3704.

[00286] In an exemplary embodiment, the expandable tubular member 3702a is then quenched in water in step 3706.

[00287] In an exemplary experimental embodiment, as illustrated in Fig. 37c, following the completion of step 3706, the expandable tubular member 3702a includes a microstructure that includes ferrite, martensite, and bainite. In an exemplary experimental embodiment, following the completion of step 3706, the expandable tubular member 3702a has a yield strength of 82 ksi, and a tensile strength of 130 ksi.

[00288] In an exemplary embodiment, the expandable tubular member 3702a is then radially expanded and plastically deformed using one or more of the methods and apparatus described above. In an exemplary embodiment, following the radial expansion and plastic deformation of the expandable tubular member 3702a, the yield strength of the expandable tubular member is about 130 ksi.

[00289] In an exemplary experimental embodiment, as illustrated in Figs. 38a-38c, one or more of the expandable tubular members, 12, 14, 24, 26, 102, 104, 106, 108, 202, 204 and/or 3502 are processed in accordance with a method 3800, in which, in step 3802, an expandable tubular member 3802a is provided that is a steel alloy having following material composition (by weight percentage): 0.08% C, 0.82% Mn, 0.006% P, 0.003% S, 0.30% Si, 0.06% Cu, 0.05% Ni, 0.05% Cr, 0.03% V, 0.03%Mo, 0.01% Nb, and 0.01% Ti. In an exemplary experimental embodiment, the expandable tubular member 3802a provided in step 3802 has a yield strength of 56 ksi, and a tensile strength of 75 ksi.

[00290] In an exemplary experimental embodiment, as illustrated in Fig. 38b, in step 3802, the expandable tubular member 3802a includes a microstructure that includes grain pearlite, widmanstatten martensite and carbides of V, Ni, and/or Ti.

[00291] In an exemplary embodiment, the expandable tubular member 3802a is then heated at a temperature of 790 °C for about 10 minutes in step 3804.

[00292] In an exemplary embodiment, the expandable tubular member 3802a is then quenched in water in step 3806.

[00293] In an exemplary experimental embodiment, as illustrated in Fig. 38c, following the completion of step 3806, the expandable tubular member 3802a includes a microstructure that includes bainite, pearlite, and new ferrite. In an exemplary experimental embodiment, following the completion of step 3806, the expandable tubular member 3802a has a yield strength of 60 ksi, and a tensile strength of 97 ksi.

[00294] In an exemplary embodiment, the expandable tubular member 3802a is then radially expanded and plastically deformed using one or more of the methods and apparatus described above. In an exemplary embodiment, following the radial expansion and plastic deformation of the expandable tubular member 3802a, the yield strength of the expandable tubular member is about 97 ksi.

[00295] Referring to Fig. 39a, an example tribological elements in a system 4000 for reducing the friction between an expansion cone and a tubular member during the expansion process, will now be described. In a system for reducing the friction between an expansion cone and a tubular member during the expansion process, there may be at least three elements contributing to friction; an expansion device 4002, a lubricant 4004, and a tubular member 4006. Elements in the expansion device 4002 that may contribute to friction comprise the following: composition 4008; geometry 4010; surface roughness 4012; texture; 4014 and coating 4016. Elements in the lubricant 4004 that may contribute to friction comprise the following: composition 4018; environmental issues 4020; and friction modifiers. Element in the tubular member 4006 that may contribute to friction comprise the following: inside diameter roughness 4022; and coating 4024. Each element may be

adjusted in the manner described below to reduce the friction between an expansion cone and a tubular member during the expansion process.

[00296] Referring to Fig. 39b, in an exemplary embodiment, during the radial expansion process, an expansion cone 5000 radially expands a tubular member 5005 by moving in an axial direction 5010 relative to the tubular member 5005. The interface between the outer surface 5010 of the tapered portion 5015 of the expansion cone 5000 and the inner surface 5020 of the tubular member 5005 includes a leading edge portion 5025 and a trailing edge portion 5030.

[00297] During the radial expansion process, the leading edge portion 5025 may be lubricated by the presence of lubricating fluids provided ahead of the expansion cone 5000. However, because the radial clearance between the expansion cone 5000 and the tubular member 5005 in the trailing edge portion 5030 during the radial expansion process is typically extremely small, and the operating contact pressures between the tubular member 5005 and the expansion cone 5000 are extremely high, the quantity of lubricating fluid provided to the trailing edge portion 5030 is typically greatly reduced. In typical radial expansion operations, this reduction in lubrication in the trailing edge portion 5030 increases the forces required to radially expand the tubular member 5005.

<u>Surface Structure of the Expansion Cone</u>

[00298] Referring to Fig. 40, an embodiment of a system for lubricating the interface between an expansion cone and a tubular member during the expansion process will now be described. As illustrated in Fig. 40, an expansion cone 5100, having a front end 5100a and a rear end 5100b, includes a tapered portion 5105 having an outer surface 3110, one or more circumferential grooves 5115a and 5115b, and one more internal flow passages 5120a and 5120b.

[00299] In an exemplary embodiment, the circumferential grooves 5115 are fluidicly coupled to the internal flow passages 5120. In this manner, during the radial expansion process, lubricating fluids are transmitted from the area ahead of the front 5100a of the expansion cone 5100 into the circumferential grooves 5115 from a lubricant source, such as, for example, from reservoir 5122 utilizing pump 5124. Thus, the trailing edge portion of the interface between the expansion cone 5100 and a tubular member is provided with an increased supply of lubricant, thereby reducing the amount of force required to radially expand the tubular member.

[00300] In an exemplary embodiment, the expansion cone 5100 includes a plurality of circumferential grooves 5115. In an exemplary embodiment, the expansion cone 5100 includes circumferential grooves 5115 concentrated about the axial midpoint of the tapered portion 5105 in order to provide lubrication to the trailing edge portion of the interface between the expansion cone 5100 and a tubular member during the radial expansion

process. In an exemplary embodiment, the circumferential grooves 5115 are equally spaced along the trailing edge portion of the expansion cone 5100 in order to provide lubrication to the trailing edge portion of the interface between the expansion cone 5100 and a tubular member during the radial expansion process.

[00301] In an exemplary embodiment, the expansion cone 5100 includes a plurality of flow passages 5120 coupled to each of the circumferential grooves 5115. In an exemplary embodiment, the cross sectional area of the circumferential grooves 5115 is greater than the cross sectional area of the flow passage 5120 in order to minimize resistance to fluid flow.

[00302] Referring to Fig. 41, another exemplary embodiment of a system for lubricating the interface between an expansion cone and a tubular member during the expansion process will now be described. As illustrated in Fig. 41, an expansion cone 5200, having a front end 5200a and a rear end 5200b, includes a tapered portion 5205 having an outer surface 5210, one or more circumferential grooves 5215a and 5215b, and one or more axial grooves 5220a and 5220b.

[00303] In an exemplary embodiment, the circumferential grooves 5215 are fluidicly coupled to the axial groves 5220. In this manner, during the radial expansion process, lubricating fluids are transmitted from the area ahead of the front 5200a of the expansion cone 5200 into the circumferential grooves 5215. Thus, the trailing edge portion of the interface between the expansion cone 5200 and a tubular member is provided with an increased supply of lubricant, thereby reducing the amount of force required to radially expand the tubular member. In an exemplary embodiment, the axial grooves 5220 are provided with lubricating fluid using a supply of lubricating fluid positioned proximate the front end 5200a of the expansion cone 5200. In an exemplary embodiment, the circumferential grooves 3215 are concentrated about the axial midpoint of the tapered portion 5205 of the expansion cone 5200 in order to provide lubrication to the trailing edge portion of the interface between the expansion cone 5200 and a tubular member during the radial expansion process. In an exemplary embodiment, the circumferential grooves 5215 are equally spaced along the trailing edge portion of the expansion cone 5200 in order to provide lubrication to the trailing edge portion of the interface between the expansion cone 5200 and a tubular member during the radial expansion process.

[00304] In an exemplary embodiment, the expansion cone 5200 includes a plurality of circumferential grooves 5215. In an exemplary embodiment, the expansion cone 5200 includes a plurality of axial grooves 5220 coupled to each of the circumferential grooves 5215. In an exemplary embodiment, the cross sectional area of the circumferential grooves 5215 is greater than the cross sectional area of the axial grooves 5220 in order to minimize resistance to fluid flow. In an exemplary embodiment, the axial groves 5220 are spaced

apart in the circumferential direction by at least about 3 inches in order to provide lubrication during the radial expansion process.

[00305] Referring to Fig. 42, another exemplary embodiment of a system for lubricating the interface between an expansion cone and a tubular member during the expansion process will now be described. As illustrated in Fig. 42, an expansion cone 5300, having a front end 5300a and a rear end 5300b, includes a tapered portion 5305 having an outer surface 5310, one or more circumferential grooves 5315a and 5315b, and one or more internal flow passages 5320a and 5320b.

[00306] In an exemplary embodiment, the circumferential grooves 5315 are fluidicly coupled to the internal flow passages 5320. In this manner, during the radial expansion process, lubricating fluids are transmitted from the areas in front of the front 5300a and/or behind the rear 5300b of the expansion cone 5300 into the circumferential grooves 5315. Thus, the trailing edge portion of the interface between the expansion cone 5300 and a tubular member is provided with an increased supply of lubricant, thereby reducing the amount of force required to radially expand the tubular member. Furthermore, the lubricating fluids also pass to the area in front of the expansion cone. In this manner, the area adjacent to the front 5300a of the expansion cone 5300 is cleaned of foreign materials. In an exemplary embodiment, the lubricating fluids are injected into the internal flow passages 5320 by pressurizing the area behind the rear 5300b of the expansion cone 5300 during the radial expansion process.

[00307] In an exemplary embodiment, the expansion cone 5300 includes a plurality of circumferential grooves 5315. In an exemplary embodiment, the expansion cone 5300 includes circumferential grooves 5315 that are concentrated about the axial midpoint of the tapered portion 5305 in order to provide lubrication to the trailing edge portion of the interface between the expansion cone 5300 and a tubular member during the radial expansion process. In an exemplary embodiment, the circumferential grooves 5315 are equally spaced along the trailing edge portion of the expansion cone 5300 in order to provide lubrication to the trailing edge portion of the interface between the expansion cone 5300 and a tubular member during the radial expansion process.

[00308] In an exemplary embodiment, the expansion cone 5300 includes a plurality of flow passages 5320 coupled to each of the circumferential grooves 5315. In an exemplary embodiment, the flow passages 5320 fluidicly coupled the front end 5300a and the rear end 5300b of the expansion cone 5300. In an exemplary embodiment, the cross sectional area of the circumferential grooves 5315 is greater than the cross-sectional area of the flow passages 5320 in order to minimize resistance to fluid flow.

[00309] Referring to Fig. 43, an embodiment of a system for lubricating the interface between an expansion cone and a tubular member during the expansion process will now be

described. As illustrated in Fig. 43, an expansion cone 5400, having a front end 5400a and a rear end 5400b, includes a tapered portion 5405 having an outer surface 5410, one or more circumferential grooves 5415a and 5415b, and one or more axial grooves 5420a and 5420b.

[00310] In an exemplary embodiment, the circumferential grooves 5415 are fluidicly coupled to the axial grooves 5420. In this manner, during the radial expansion process, lubricating fluids are transmitted from the areas in front of the front 5400a and/or behind the rear 5400b of the expansion cone 5400 into the circumferential grooves 5415. Thus, the trailing edge portion of the interface between the expansion cone 5400 and a tubular member is provided with an increased supply of lubricant, thereby reducing the amount of force required to radially expand the tubular member. Furthermore, In an exemplary embodiment, pressurized lubricating fluids pass from the fluid passages 5420 to the area in front of the front 5400a of the expansion cone 5400. In this manner, the area adjacent to the front 5400a of the expansion cone 5400 is cleaned of foreign materials. In an exemplary embodiment, the lubricating fluids are injected into the internal flow passages 5420 by pressurizing the area behind the rear 5400b expansion cone 5400 during the radial expansion process.

[00311] In an exemplary embodiment, the expansion cone 5400 includes a plurality of circumferential grooves 5415. In an exemplary embodiment, the expansion cone 5400 includes circumferential grooves 5415 that are concentrated about the axial midpoint of the tapered portion 5405 in order to provide lubrication to the trailing edge portion of the interface between the expansion cone 5400 and a tubular member during the radial expansion process. In an exemplary embodiment, the circumferential grooves 5415 are equally spaced along the trailing edge portion of the expansion cone 5400 in order to provide lubrication to the trailing edge portion of the interface between the expansion cone 5400 and a tubular member during the radial expansion process.

[00312] In an exemplary embodiment, the expansion cone 5400 includes a plurality of axial grooves 5420 coupled to each of the circumferential grooves 5415. In an exemplary embodiment, the axial grooves 5420 fluidicly coupled the front end and the rear end of the expansion cone 5400. In an exemplary embodiment, the cross sectional area of the circumferential grooves 5415 is greater than the cross sectional area of the axial grooves 5420 in order to minimize resistance to fluid flow. In an exemplary embodiment, the axial grooves 5420 are spaced apart in the circumferential direction by at least about 3 inches in order to provide lubrication during the radial expansion process.

[00313] Referring to Fig. 44, another exemplary embodiment of a system for lubricating the interface between an expansion cone and a tubular member during the expansion process will now be described. As illustrated in Fig. 44, an expansion cone 5500, having a front end 5500a and a rear end 5500b, includes a tapered portion 5505 having an

outer surface 5510, one or more circumferential grooves 5515a and 5515b, and one or more axial grooves 5520a and 5520b.

[00314] In an exemplary embodiment, the circumferential grooves 5515 are fluidicly coupled to the axial grooves 5520. In this manner, during the radial expansion process, lubricating fluids are transmitted from the area ahead of the front 5500a of the expansion cone 5500 into the circumferential grooves 5515. Thus, the trailing edge portion of the interface between the expansion cone 5500 and a tubular member is provided with an increased supply of lubricant, thereby reducing the amount of force required to radially expand the tubular member. In an exemplary embodiment, the lubricating fluids are injected into the axial grooves 5520 using a fluid conduit that is coupled to the tapered end 3205 of the expansion cone 3200.

[00315] In an exemplary embodiment, the expansion cone 5500 includes a plurality of circumferential grooves 5515. In an exemplary embodiment, the expansion cone 5500 includes circumferential grooves 5515 that are concentrated about the axial midpoint of the tapered portion 5505 in order to provide lubrication to the trailing edge portion of the interface between the expansion cone 5500 and a tubular member during the radial expansion process. In an exemplary embodiment, the circumferential grooves 5515 are equally spaced along the trailing edge portion of the expansion cone 5500 in order to provide lubrication to the trailing edge portion of the interface between the expansion cone 5500 and a tubular member during the radial expansion process.

[00316] In an exemplary embodiment, the expansion cone 5500 includes a plurality of axial grooves 5520 coupled to each of the circumferential grooves 5515. In an exemplary embodiment, the axial grooves 5520 intersect each of the circumferential groves 5515 at an acute angle. In an exemplary embodiment, the cross sectional area of the circumferential grooves 5515 is greater than the cross sectional area of the axial grooves 5520. In an exemplary embodiment, the axial grooves 5520 are spaced apart in the circumferential direction by at least about 3 inches in order to provide lubrication during the radial expansion process. In an exemplary embodiment, the axial grooves 5520 intersect the longitudinal axis of the expansion cone 5500 at a larger angle than the angle of attack of the tapered portion 5505 in order to provide lubrication during the radial expansion process.

[00317] Referring to Fig. 45, another exemplary embodiment of a system for lubricating the interface between an expansion cone and a tubular member during the expansion process will now be described. As illustrated in Fig. 45, an expansion cone 5600, having a front end 5600a and a rear end 5600b, includes a tapered portion 5605 having an outer surface 5610, a spiral circumferential groove 5615, and one or more internal flow passages 5620.

[00318] In an exemplary embodiment, the circumferential groove 5615 is fluidicly coupled to the internal flow passage 5620. In this manner, during the radial expansion process, lubricating fluids are transmitted from the area ahead of the front 5600a of the expansion cone 5600 into the circumferential groove 5615, such as, for example, from reservoir 5622 utilizing pump 5624. Thus, the trailing edge portion of the interface between the expansion cone 5600 and a tubular member is provided with an increased supply of lubricant, thereby reducing the amount of force required to radially expand the tubular member. In an exemplary embodiment, the lubricating fluids are injected into the internal flow passage 5620 using a fluid conduit that is coupled to the tapered end 5605 of the expansion cone 5600.

[00319] In an exemplary embodiment, the expansion cone 5600 includes a plurality of spiral circumferential grooves 5615. In an exemplary embodiment, the expansion cone 5600 includes circumferential grooves 5615 that are concentrated about the axial midpoint of the tapered portion 5605 in order to provide lubrication to the trailing edge portion of the interface between the expansion cone 5600 and a tubular member during the radial expansion process. In an exemplary embodiment, the circumferential grooves 5615 are equally spaced along the trailing edge portion of the expansion cone 5600 in order to provide lubrication to the trailing edge portion of the interface between the expansion cone 5600 and a tubular member during the radial expansion process.

[00320] In an exemplary embodiment, the expansion cone 5600 includes a plurality of flow passages 5620 coupled to each of the circumferential grooves 5615. In an exemplary embodiment, the cross sectional area of the circumferential groove 5615 is greater than the cross sectional area of the flow passage 5620 in order to minimize resistance to fluid flow.

[00321] Referring to Fig. 46, another exemplary embodiment of a system for lubricating the interface between an expansion cone and a tubular member during the expansion process will now be described. As illustrated in Fig. 46, an expansion cone 5700, having a front end 5700a and a rear end 5700b, includes a tapered portion 5705 having an outer surface 5710, a spiral circumferential groove 5715, and one or more axial grooves 5720a, 5720b and 5720c.

[00322] In an exemplary embodiment, the circumferential groove 5715 is fluidicly coupled to the axial grooves 5720. In this manner, during the radial expansion process, lubricating fluids are transmitted from the area ahead of the front 5700a of the expansion cone 5700 into the circumferential groove 5715. Thus, the trailing edge portion of the interface between the expansion cone 5700 and a tubular member is provided with an increased supply of lubricant, thereby reducing the amount of force required to radially expand the tubular member. In an exemplary embodiment, the lubricating fluids are injected

into the axial grooves 5720 using a fluid conduit that is coupled to the tapered end 5705 of the expansion cone 5700.

[00323] In an exemplary embodiment, the expansion cone 5700 includes a plurality of spiral circumferential grooves 5715. In an exemplary embodiment, the expansion cone 5700 includes circumferential grooves 5715 concentrated about the axial midpoint of the tapered portion 5705 in order to provide lubrication to the trailing edge portion of the interface between the expansion cone 5700 and a tubular member during the radial expansion process. In an exemplary embodiment, the circumferential grooves 5715 are equally spaced along the trailing edge portion of the expansion cone 5700 in order to provide lubrication to the trailing edge portion of the interface between the expansion cone 5700 and a tubular member during the radial expansion process.

[00324] In an exemplary embodiment, the expansion cone 5700 includes a plurality of axial grooves 5720 coupled to each of the circumferential grooves 5715. In an exemplary embodiment, the axial grooves 5720 intersect the circumferential grooves 5715 in a perpendicular manner. In an exemplary embodiment, the cross sectional area of the circumferential groove 5715 is greater than the cross sectional area of the axial grooves 5720 in order to minimize resistance to fluid flow. In an exemplary embodiment, the circumferential spacing of the axial grooves is greater than about 3 inches in order to provide lubrication during the radial expansion process. In an exemplary embodiment, the axial grooves 5720 intersect the longitudinal axis of the expansion cone at an angle greater than the angle of attack of the tapered portion 5705 in order to provide lubrication during the radial expansion process.

[00325] Referring to Fig. 47, an embodiment of a system for lubricating the interface between an expansion cone and a tubular member during the expansion process will now be described. As illustrated in Fig. 47, an expansion cone 5800, having a front end 5800a and a rear end 5800b, includes a tapered portion 5805 having an outer surface 5810, a circumferential groove 5815, a first axial groove 5820, and one or more second axial grooves 5825a, 5825b, 5825c and 5825d.

[00326] In an exemplary embodiment, the circumferential groove 5815 is fluidicly coupled to the axial grooves 5820 and 5825. In this manner, during the radial expansion process, lubricating fluids are transmitted from the area behind the back 5800b of the expansion cone 5800 into the circumferential groove 5815. Thus, the trailing edge portion of the interface between the expansion cone 5800 and a tubular member is provided with an increased supply of lubricant, thereby reducing the amount of force required to radially expand the tubular member. In an exemplary embodiment, the lubricating fluids are injected into the first axial groove 5820 by pressurizing the region behind the back 5800b of the expansion cone 5800. In an exemplary embodiment, the lubricant is further transmitted into

the second axial grooves 5825 where the lubricant preferably cleans foreign materials from the tapered portion 5805 of the expansion cone 5800.

[00327] In an exemplary embodiment, the expansion cone 5800 includes a plurality of circumferential grooves 5815. In an exemplary embodiment, the expansion cone 5800 includes circumferential grooves 5815 concentrated about the axial midpoint of the tapered portion 5805 in order to provide lubrication to the trailing edge portion of the interface between the expansion cone 5800 and a tubular member during the radial expansion process. In an exemplary embodiment, the circumferential grooves 5815 are equally spaced along the trailing edge portion of the expansion cone 5800 in order to provide lubrication to the trailing edge portion of the interface between the expansion cone 5800 and a tubular member during the radial expansion process.

[00328] In an exemplary embodiment, the expansion cone 5800 includes a plurality of first axial grooves 5820 coupled to each of the circumferential grooves 5815. In an exemplary embodiment, the first axial grooves 5820 extend from the back 5800b of the expansion cone 5800 and intersect the circumferential groove 5815. In an exemplary embodiment, the first axial groove 5820 intersects the circumferential groove 5815 in a perpendicular manner. In an exemplary embodiment, the cross sectional area of the circumferential groove 5815 is greater than the cross sectional area of the first axial groove 5820 in order to minimize resistance to fluid flow. In an exemplary embodiment, the circumferential spacing of the first axial grooves 5820 is greater than about 3 inches in order to provide lubrication during the radial expansion process.

[00329] In an exemplary embodiment, the expansion cone 5800 includes a plurality of second axial grooves 5825 coupled to each of the circumferential grooves 5815. In an exemplary embodiment, the second axial grooves 5825 extend from the front 5800a of the expansion cone 5800 and intersect the circumferential groove 5815. In an exemplary embodiment, the second axial grooves 5825 intersect the circumferential groove 5815 in a perpendicular manner. In an exemplary embodiment, the cross sectional area of the circumferential groove 5815 is greater than the cross sectional area of the second axial grooves 5825 in order to minimize resistance to fluid flow. In an exemplary embodiment, the circumferential spacing of the second axial grooves 5825 is greater than about 3 inches in order to provide lubrication during the radial expansion process. In an exemplary embodiment, the second axial grooves 5825 intersect the longitudinal axis of the expansion cone 5800 at an angle greater than the angle of attack of the tapered portion 5805 in order to provide lubrication during the radial expansion process.

[00330] Referring to Fig. 48, an embodiment of a system for lubricating the interface between an expansion cone and a tubular member during the expansion process will now be described. As illustrated in Fig. 48, an expansion cone 5900, having a front end 5900a and a

rear end 5900b, includes a tapered portion 5905 having an outer surface 5910, one or more circumferential grooves 5915a and 5915b, one or more radial passageways 5916 and one more internal flow passages 5920.

[00331] In an exemplary embodiment, the circumferential groove 5915a is fluidicly coupled to the internal flow passages 5920. In this manner, during the radial expansion process, lubricating fluids are transmitted from the area ahead of the front 5900a of the expansion cone 5900 into the circumferential grooves 5915, such as, for example, from reservoir 5922 utilizing pump 5924. Thus, the trailing edge portion of the interface between the expansion cone 5900 and a tubular member is provided with an increased supply of lubricant, thereby reducing the amount of force required to radially expand the tubular member.

[00332] In an exemplary embodiment, the expansion cone 5900 includes a plurality of circumferential grooves 5915a. In an exemplary embodiment, the expansion cone 5900 includes circumferential grooves 5915a concentrated about the axial midpoint of the tapered portion 5905 in order to provide lubrication to the trailing edge portion of the interface between the expansion cone 5900 and a tubular member during the radial expansion process. In an exemplary embodiment, the circumferential grooves 5915 are equally spaced along the trailing edge portion of the expansion cone 5900 in order to provide lubrication to the trailing edge portion of the interface between the expansion cone 5900 and a tubular member during the radial expansion process.

[00333] In an exemplary embodiment, the expansion cone 5900 includes a plurality of flow passages coupled to each of the circumferential grooves 5915a. In another embodiment, circumferential groove 5915b, which is not fluidicly coupled to the internal flow passages, may also be included.

[00334] Referring to Fig. 49, an embodiment of a system for lubricating the interface between an expansion cone and a tubular member during the expansion process will now be described. As illustrated in Fig. 49, an expansion cone 6000, having a front end 6000a and a rear end 6000b, includes a tapered portion 6005 having an outer surface 6010, one or more circumferential grooves 6015, one or more radial passageways 6016 and one or more internal flow passages 6020.

[00335] In an exemplary embodiment, the circumferential grooves 6015 are fluidicly coupled to the internal flow passages 6020. In this manner, during the radial expansion process, lubricating fluids are transmitted from the area ahead of the front 6000a of the expansion cone 6000 into the circumferential grooves 6015, such as, for example, from reservoir 6022 utilizing pump 6024. Thus, the trailing edge portion of the interface between the expansion cone 6000 and a tubular member is provided with an increased supply of

lubricant, thereby reducing the amount of force required to radially expand the tubular member.

[00336] In an exemplary embodiment, the expansion cone 6000 includes a plurality of circumferential grooves 6015. In an exemplary embodiment, the expansion cone 6000 includes circumferential grooves 6015 concentrated about the axial midpoint of the tapered portion 6005 in order to provide lubrication to the trailing edge portion of the interface between the expansion cone 6000 and a tubular member during the radial expansion process. In an exemplary embodiment, the circumferential grooves 6015 are equally spaced along the trailing edge portion of the expansion cone 6000 in order to provide lubrication to the trailing edge portion of the interface between the expansion cone 6000 and a tubular member during the radial expansion process.

[00337] In an exemplary embodiment, the expansion cone 6000 includes a plurality of flow passages coupled to each of the circumferential grooves 6015.

[00338] Referring to Fig. 50, an embodiment of a system for lubricating the interface between an expansion cone and a tubular member during the expansion process will now be described. As illustrated in Fig. 50, an expansion cone 6100, having a front end 6100a and a rear end 6100b, includes a tapered portion 6105 having an outer surface 6110, one or more circumferential grooves 6115a and 6115b, one or more radial passageways 6116 and one more internal flow passages 6120.

[00339] In an exemplary embodiment, the circumferential groove 6115a is fluidicly coupled to the internal flow passages 6120. In this manner, during the radial expansion process, lubricating fluids are transmitted from the area ahead of the front 6100a of the expansion cone 6100 into the circumferential grooves 6115, such as, for example, from reservoir 6122 utilizing pump 6124. Thus, the trailing edge portion of the interface between the expansion cone 6100 and a tubular member is provided with an increased supply of lubricant, thereby reducing the amount of force required to radially expand the tubular member.

[00340] In an exemplary embodiment, the expansion cone 6100 includes a plurality of circumferential grooves 6115a. In an exemplary embodiment, the expansion cone 6100 includes circumferential grooves 6115a concentrated about the axial midpoint of the tapered portion 6105 in order to provide lubrication to the trailing edge portion of the interface between the expansion cone 6100 and a tubular member during the radial expansion process. In an exemplary embodiment, the circumferential grooves 6115a are equally spaced along the trailing edge portion of the expansion cone 6100 in order to provide lubrication to the trailing edge portion of the interface between the expansion cone 6100 and a tubular member during the radial expansion process.

[00341] In an exemplary embodiment, the expansion cone 6100 includes a plurality of flow passages coupled to each of the circumferential grooves 6115a. Alternatively, circumferential groove 6115b, which is not fluidicly coupled to the internal flow passages, may also be included.

[00342] Referring to Fig. 51, another exemplary embodiment of a system for lubricating the interface between an expansion cone and a tubular member during the expansion process will now be described. As illustrated in Fig. 51, an expansion cone 6200, having a front end 6200a and a rear end 6200b, includes a tapered portion 6205 having an outer surface 6210, circumferential grooves 6215 arranged in a helical crisscrossing pattern, one or more radial passageways 6216 and one or more internal flow passages 6220.

[00343] In an exemplary embodiment, the circumferential grooves 6215 are fluidicly coupled to each other and to the internal flow passages 6220. In this manner, during the radial expansion process, lubricating fluids are transmitted from the area ahead of the front 6200a of the expansion cone 6200 into the circumferential grooves 6215, such as, for example, from reservoir 6222 utilizing pump 6224. Thus, the trailing edge portion of the interface between the expansion cone 6200 and a tubular member is provided with an increased supply of lubricant, thereby reducing the amount of force required to radially expand the tubular member.

[00344] In an exemplary embodiment, the expansion cone 6200 includes a plurality of circumferential grooves 6215 arranged in a pinecone design. In an exemplary embodiment, the expansion cone 6200 includes circumferential grooves 6215 concentrated about the axial midpoint of the tapered portion 6205 in order to provide lubrication to the trailing edge portion of the interface between the expansion cone 6200 and a tubular member during the radial expansion process. In an exemplary embodiment, the circumferential grooves 6215 are equally spaced along the trailing edge portion of the expansion cone 6200 in order to provide lubrication to the trailing edge portion of the interface between the expansion cone 6200 and a tubular member during the radial expansion process.

[00345] Referring to Fig. 52, an alternate exemplary embodiment of the system for lubricating the interface between an expansion cone and a tubular member during the expansion process shown in Fig. 51 will now be described. As illustrated in Fig. 52, an expansion cone 6200, having a front end 6200a and a rear end 6200b, includes a tapered portion 6205 having an outer surface 6210, circumferential grooves 6215 arranged in a helical crisscrossing pattern over the entire outer surface 6210, one or more radial passageways 6216 and one or more internal flow passages 6220.

[00346] In an exemplary embodiment, the circumferential grooves 6218 are fluidicly coupled to each other and to the internal flow passages 6220. In this manner, during the radial expansion process, lubricating fluids are transmitted from the area ahead of the front

6200a of the expansion cone 6200 into the circumferential grooves 6218, such as, for example, from reservoir 6222 utilizing pump 6224. Thus, the trailing edge portion of the interface between the expansion cone 6200 and a tubular member is provided with an increased supply of lubricant, thereby reducing the amount of force required to radially expand the tubular member.

[00347] In an exemplary embodiment, a second circumferential groove 6226 is fluidicly coupled to the circumferential grooves 6218.

[00348] Referring to Fig. 53, another exemplary embodiment of a system for lubricating the interface between an expansion cone and a tubular member during the expansion process will now be described. As illustrated in Fig. 53, an expansion cone 6300, having a front end 6300a and a rear end 6300b, includes a tapered portion 6305 having an outer surface 6310, circumferential grooves 6315 arranged in a helical crisscrossing pattern, one or more radial passageways 6316 and one or more internal flow passages 6320.

[00349] In an exemplary embodiment, the circumferential grooves 6315 are fluidicly coupled to each other and one more internal flow passages 6320. In this manner, during the radial expansion process, lubricating fluids are transmitted from the area ahead of the front 6300a of the expansion cone 6300 into the circumferential grooves 6315, such as, for example, from reservoir 6322 utilizing pump 6324. Thus, the trailing edge portion of the interface between the expansion cone 6300 and a tubular member is provided with an increased supply of lubricant, thereby reducing the amount of force required to radially expand the tubular member. In an exemplary embodiment, the lubricating fluids are injected into the axial grooves 6320 using a fluid conduit that is coupled to the tapered end 6305 of the expansion cone 6300.

[00350] In an exemplary embodiment, the expansion cone 6300 includes a plurality of spiral circumferential grooves 6315. In an exemplary embodiment, the expansion cone 6300 includes circumferential grooves 6315 concentrated about the axial midpoint of the tapered portion 6305 in order to provide lubrication to the trailing edge portion of the interface between the expansion cone 6300 and a tubular member during the radial expansion process. In an exemplary embodiment, the circumferential grooves 6315 are equally spaced along the trailing edge portion of the expansion cone 6300 in order to provide lubrication to the trailing edge portion of the interface between the expansion cone 6300 and a tubular member during the radial expansion process. In an exemplary embodiment, the axial grooves 6320 intersect each other in a perpendicular manner.

[00351] Referring to Fig. 54, an alternate exemplary embodiment of the a system for lubricating the interface between an expansion cone and a tubular member during the expansion process shown in Fig. 53 will now be described. As illustrated in Fig. 54, an expansion cone 6300, having a front end 6300a and a rear end 6300b, includes a tapered

portion 6305 having an outer surface 6310, circumferential grooves 6315 arranged in a helical crisscrossing pattern over the substantially all of the outer surface 6310, one or more radial passageways 6316 and one more internal flow passages 6320.

[00352] In an exemplary embodiment, the circumferential grooves 6318 are fluidicly coupled to each other and to the internal flow passages 6320. In this manner, during the radial expansion process, lubricating fluids are transmitted from the area ahead of the front 6300a of the expansion cone 6300 into the circumferential grooves 6318, such as, for example, from reservoir 6322 utilizing pump 6324. Thus, the trailing edge portion of the interface between the expansion cone 6300 and a tubular member is provided with an increased supply of lubricant, thereby reducing the amount of force required to radially expand the tubular member.

[00353] In an exemplary embodiment, a second circumferential groove 6326 is fluidicly coupled to the circumferential grooves 6318.

[00354] Referring to Fig. 55, in an exemplary embodiment, circumferential groove 6415 may be utilized on the outer surfaces 5101, 5210, 5310, 5410, 5510, 5610, 5710, 5810, 5910, 6010, 6110, 6210, and 6310 in one or more of expansion cones 5100, 5200, 5300, 5400, 5500, 5600, 5700, 5800, 5900, 6000, 6100, 6200, and 6300. Furthermore, it may be implemented in any expansion device including one ore more expansion surfaces. In an exemplary embodiment, circumferential groove 6415 is positioned in tapered portion 6405 with first edge 6430 on outer surface 6410a having a first radius of curvature and second edge 6434 on outer surface 6410b having a second radius of curvature. The radius on the trailing edge 6434 may be much larger than the radius on the leading edge 6430 to assist lubricant delivery.

[00355] Referring to Fig. 56, in an exemplary embodiment, outer surfaces 6410a and 6410b of tapered portion 6405 are tapered at angle β. The angle that is generated by radius of curvature of second edge 6434 and the tubular member is the sliding angle, which may be important for adequate delivery of lubricant. If the sliding angle is too large or too small, then the trailing edge may act as a wiper, which may remove lubricant form the working area. The radius of curvature of second edge 6434 and the sliding angle are at least dependent on the lubricant viscosity, pipe diameter and friction between the expansion cone and the tubular member. Each cone surface channel design may be empirically design by testing cones in stages to determine the optimum friction-reducing configuration.

[00356] In an exemplary embodiment, outer surfaces 6410a and 6410b of tapered portion 6405 are tapered at angle β. In an exemplary embodiment, the angle β may range from 8.5 degrees to 12.5 degrees, such as, for example, 10 degrees. The width 6442 of circumferential groove 6415 may be as small as possible to maximize the area of outer surfaces 6410a and 6410b in contact with the inner surface of the tubular member for radial

expansion. In an exemplary embodiment, the radius of curvature 6446 of second edge 6434, which may be defined as the perpendicular to the tangent 6448 at the point where vertical projection line 6450 intersects second edge 6434, may be positioned relative to the bottom of circumferential groove at angle α, the sliding angle. In an exemplary embodiment, angle α may be less than or equal to 30 degrees, such as, for example 10 degrees, causing lubricant in the circumferential groove 6415to be drawn efficiently on to the inner surface of the tubular member during radial expansion.

[00357] Referring to Fig. 57, In an exemplary embodiment, circumferential groove 6518 may be achieved by indenting a portion of the expansion cone on the tapered portion 6505a thereby creating a lip 6515 between tapered portion 6505a and second tapered portion 6505b. In an exemplary embodiment, tapered portions, 6505a and 6505b, are at the same angle β. Width y of circumferential groove 6518 from lip 6515 to the location where taper portion 6505b is at the same angle β tapered portion 6505a may be wide enough to supply sufficient lubricant to the tubular member, thereby reducing the amount of force required to radially expand the tubular member. Vertical portion 6520 in tapered portion 6505a having width x exists to reduce the mechanical stress at corner 6552 due to corner loading. The vertical portion 6520 is not critical to the operation of the circumferential groove 6518 and hence the width x of the vertical portion 6520 is not critical. However, width x of vertical portion 6520 may be small enough to maximize the amount of contact between the expansion cone and the tubular member during radial expansion, yet large enough to reduce the mechanical stress at corner 6552. In determining the width x of the vertical portion 6520 and width y of the circumferential groove 6518 under lip 6515, the following factors may be addressed: the size of the expansion cone; the viscosity of the lubricant; and the lubrication injection pressure. Width y of the circumferential groove 6518 may be as small possible to maximize the area of outer surfaces, 6510a and 6510b, in contact with the surface of the tubular member for radial expansion.

[00358] Referring to Figs. 58a, 58b and 58c, an exemplary embodiment of a system for lubricating the interface between an expansion cone and a tubular member during the expansion process shown will now be described. As illustrated in Figs. 58a, 58b and 58c, expansion cone 6600, having a front end 6600a and a rear end 6600b, includes a tapered portions 6605a and 6605b and lip 6615.

[00359] In an exemplary embodiment, the circumferential groove 6618 under lip 6615 is fluidicly coupled to the internal flow passages 6660 through port 6662. In this manner, during the radial expansion process, lubricating fluids are transmitted from the area ahead of the front end 6600a of the expansion cone 6600 under lip 6615. Thus, the trailing edge portion of the interface between the expansion cone 6600 and a tubular member is provided

with an increased supply of lubricant, thereby reducing the amount of force required to radially expand the tubular member.

[00360] In an exemplary embodiment, exemplary relative dimensions of the elements of Figs. 58a, 58b and 58c are as follows:

1. taper angle β of tapered portions 6605a and 6605b – 10 degrees;
2. width x - 0.125;
3. radius of curvature of the top edge 6670 – 0.500;
4. radius of curvature of the first edge 6650 – 0.02;
5. width of the circumferential groove 6618 under lip 6615 – 0.020 - .060;
6. height of the cone 6672 – 1.887;
7. height 6682 of the expansion cone beneath the tapered portion 6605b – 0.895;
8. diameter 6678 of the cone at front end 6600a – 1.380.
9. diameter 6676 of the cone at rear end 6600b – 1.656; and
10. depth 6680 of the vertical portion between the top and first edges – 0.015.

[00361] Referring to Figs. 59a and 59b, another exemplary embodiment of a system for lubricating the interface between an expansion cone and a tubular member during the expansion process will now be described. As illustrated in Figs. 59a and 59b, an expansion cone 6700, having a front end 6700a and a rear end 6700b, includes a tapered portion 6705 having an outer surface 6710, internal flow passage 6730 and one or more axial grooves 6720.

[00362] In an exemplary embodiment, during the radial expansion process, the axial grooves 6720 may be fluidicly coupled to the area ahead of the front end 6700a of the expansion cone 6700 to receive lubricant. Thus, the trailing edge portion of the interface between the expansion cone and a tubular member is provided with an increased supply of lubricant, thereby reducing the amount of force required to radially expand the tubular member. In an exemplary embodiment, the axial grooves 6720 are provided with lubricating fluid using a supply of lubricating fluid positioned proximate the front end 6700a of the expansion cone 6700.

[00363] In an exemplary embodiment, example relative dimensions of the elements of in Figs. 59a and 59b are as follows:

1. taper angle β of tapered portion 6605 – 10 degrees;
2. channel 6720 depth - 0.020;
3. channel 6720 diameter - 0.040;
4. radius of curvature of the bottom of taper portion 6705 – 0.500;
5. number of axial grooves 6720 – 8;
6. height of the expansion cone 6700 – 1.678;
7. height of the expansion cone 6700 beneath the tapered portion 6705 – 0.895;

8. diameter 6778 of the expansion cone 6700 at front end 6600a – 1.380; and
9. diameter 6776 of the expansion cone 6700 at rear end 6600b – 1.656.

[00364] Referring to Figs. 60a, 60b and 60c, another exemplary embodiment of a system for lubricating the interface between an expansion cone and a tubular member during the expansion process will now be described. As illustrated in Figs. 60a, 60b and 60c, an expansion cone 6800, having a front end 6800a and a rear end 6800b, includes a tapered portion 6805 having an outer surface 6810, which includes a tapered faceted polygonal outer expansion surface 6802. Tapered faceted polygonal outer expansion surface 6802 includes circumferential spaced apart contact points 6810 that may be in contact with the inside surface of a tubular member during radial expansion and recesses 6912. When expansion cone circumferential spaced apart contact points 6810 are in contact with a tubular member 6820, the recesses 6812 combine with the inside surface of the tubular member to form lubricant gaps 6822 between the tubular member, circumferential spaced apart contact points 6810 and recesses 6812. The lubricant gaps may act as a high-pressure lubrication channel. Internal passageway 6804 is fluidicly connected to radial ports 6806, which may supply lubricant to lubricant gaps.

[00365] Referring to Figs. 61a, 61b, 61c, 61d and 61e another exemplary embodiment of a system shown in for lubricating the interface between an expansion cone having tapered faceted polygonal outer expansion surface and a tubular member during the expansion process will now be described. As illustrated in Fig. 61a and 61b, an expansion cone 6900, includes circumferential spaced apart contact points 6910, recesses 6912 around the perimeter of the expansion cone, internal passage 6930 for drilling fluid, internal passages 6914 for lubricating fluids, and radial passageways 6916.

[00366] Figs. 61c and 61d illustrate expansion cone 6900 in contact with tubular member 6920 at circumferential spaced apart contact points 6910 around the perimeter of expansion cone 6900. Lubricant gaps 6922 exist between recesses 6912 and tubular member 6920 and are fluidicly coupled to internal passages 6914 to act as a high-pressure lubrication channels to increased supply of lubricant, thereby reducing the amount of force required to radially expand tubular member 6920. Lubricant gaps 6922 provide additional high-pressure lubrication channels, which may assist in lubricating the tubular member where needed most, at the high load contact edge.

[00367] Referring to Fig. 61e, an expansion cone having a tapered faceted polygonal outer expansion surface with contact points, such as, for example, circumferential spaced apart contact points 6910 and 6910, may compensate for non-uniform wall thickness tubular member 6940, by applying localized higher loads at the polygon contact points. In an exemplary embodiment of expansion cone 6900 having tapered faceted polygonal outer expansion surface in contact with tubular member 6940 having a non-uniform wall thickness

is shown. The high load circumferential spaced apart contact points may radially expand and plastically deform the thick wall areas T2 as well as the thin wall areas T1, instead of taking the path of least resistance, which may assist in maintaining a proportional wall thickness during the radial expansion and plastic deformation process.

[00368] The number of circumferential spaced apart contact points, 6810 and 6910, having width (W) around the circumference of an expansion cone may vary for different sizes of expandable tubular members. Several factors may be considered when determining the appropriate number contact points, 6810 and 6910, such as, for example, the coefficient of friction between the expansion cone and the expandable tubular member, pipe quality, and data from lubrication tests. For the ideal tubular member with uniform thickness, the number of circumferential spaced apart contact points may be infinity. Thus, the dimensions of the final design of an expansion cone may ultimately be refined by performing an empirical study.

[00369] In an exemplary embodiment, the following equations may be used to make a preliminary calculation of the optimum number of circumferential spaced apart contact points, 6810 and 6910, on an expansion cone, 6800 and 6900, having a tapered faceted polygonal outer expansion surface for expanding an expandable tubular member having an original inside diameter of 4.77" to an inside diameter of 5.68" utilizing an expansion cone, including a lubricant gap depth of .06":

$$R=(D_1+D_{exp})/2= (4.77-5.68)/2= .42; \quad (5)$$

$$\text{Sin } (\alpha/2) = 1-(H/R) = 1-(.06/.42); \quad (6)$$

$$\alpha/2= 12.3°; \quad (7)$$

$$\alpha= 24.6; \quad (8)$$

$$N = 360°/\alpha= 360°/24.6°= 15; \quad (9)$$

where,

D_1= Original tubular member inside diameter;

D_{exp}= Expanded tubular member inside diameter;

H= Gap between gap surface and tubular member inside diameter;

R= Radius of polygon at midpoint of expansion cone;

α= Angle between circumferential spaced apart contact points of polygon; and

N= Number of polygon flat surfaces.

Accordingly, the theoretical number (N) of circumferential spaced apart contact points, 6810 and 6910, on an expansion cone having a tapered faceted polygonal outer expansion surface is 15, but the actual number that may result from an empirical analysis may depend

on tubular member quality, coefficient of friction, and data from lubrication tests. In an exemplary embodiment, a range for the actual number (N) of circumferential spaced apart contact points necessary to expand an expandable tubular member having an original inside diameter of 4.77" to an inside diameter of 5.68" I.D. may range from 12-15.

[00370] Referring to Figs. 62a, 62b and 62c, another exemplary embodiment of the system shown in Figs. 60a and 60b for lubricating the interface between an expansion cone having tapered faceted polygonal outer expansion surface and a tubular member during the expansion process will now be described. As illustrated in Fig. 62a, an expansion cone 7000, having a front end 7000a and a rear end 7000b, includes a tapered portion 7005, contact surfaces 7010, recesses 7012, internal passage 7030 for drilling fluid, internal passages 7014 for lubricating fluids, and radial passageways 7016. The width 7020 of contact surfaces 7010 of expansion cone 7000 may be constant for the length of the cone, resulting in trapezoidal shaped lubricant gap 7022 between each contact surface 7010. The following equations may be used for calculating the width (W) 7020 of the contact surface:

$$W = [2R \sin(\alpha/2)] / K; \qquad (10)$$

$$R = (D1+D2)/4; \qquad (11)$$

$$\alpha = 360 \text{ degrees}/ N; \qquad (12)$$

where:

W = Width of contact point;

D1 = initial tubular member diameter;

D2 = expanded diameter;

N= Number of polygon flat surfaces; and

K= System friction coefficient that must be determined.

In an exemplary embodiment, K is between 3 to 5 for an expandable tubular member having an original inside diameter of 4.77" and an expanded inside diameter of 5.68" may range from 12-15. In an exemplary embodiment, K is 4.2.

[00371] Referring now to Fig . 62d, 62e and 62f another exemplary embodiment of the system shown in Figs. 60a, 60b and 61 for lubricating the interface between an expansion cone having tapered faceted polygonal outer expansion surface and a tubular member during the expansion process will now be described. As illustrated in Fig. 62b, an expansion cone 7100, having a front end 7100a and a rear end 7100b, includes a tapered portion 7105, contact surfaces 7110, recesses 7112, internal passage 7130 for drilling fluid, internal passages 7114 for lubricating fluids, and radial passageways 7116. The width 7120 of contact surfaces 7110 of expansion cone 7100 may vary the length of the cone. In an exemplary embodiment, width 7120 of contact surfaces 7110 may be larger at the front end 7100a W1 and become smaller toward the rear end 7100b W2.

[00372] In several exemplary embodiments, tapered faceted polygonal outer expansion surface of an expansion cone may be implemented in any expansion cone, including one or more of expansion cones 5100, 5200, 5300, 5400, 5500, 5600, 5700, 5800, 5900, 6000, 6100, 6200, 6300 and 6600. Furthermore, it may be implemented in any expansion device including one ore more expansion surfaces.

[00373] The angle of the tapered portion of each expansion cone, the cone angle, in the system for lubricating the interface between an expansion cone and a tubular member during the expansion process, including the tapered portions in expansion cones 5100, 5200, 5300, 5400, 5500, 5600, 5700, 5800, 5900, 6000, 6100, 6200, 6300, 6600, 6700, 6800, 6900, 7000 and 7100, may be dependant on the amount of friction between the tapered portion of the expansion cone and the inside diameter of the tubular member. In an exemplary experimental embodiment, a cone angle of 8.5° to 12.5° was shown to be sufficient to expand an expandable tubular member having an original inside diameter of 4.77" to an inside diameter of 5.68". The optimum cone angle may be determined after testing the lubricant system to determine the exact coefficient of friction. A cone angle greater than 10° may be required to minimize the effect of thinning the tubular member wall during expansion and may potentially reduce failures related to collapsing.

[00374] In several exemplary embodiments, one or more of the expansion cones 5100, 5200, 5300, 5400, 5500, 5600, 5700, 5800, 5900, 6000, 6100, 6200, 6300, 6600, 6700, 6800, 6900, 7000 and 7100 may or may not have internal passages. In another embodiment, a plurality of inserts having internal flow passages may be provided in the expansion cone internal flow passages, The internal flow passages of each insert may vary in size. In this manner, a expansion cone flow passage may be machined to a standard size, and the lubricant supply may be varied by using different inserts having different sized internal flow passages. Each insert may include a filter for filtering particles and other foreign materials from the lubricant that passes into the flow passage. In this manner, the foreign materials are prevented from clogging the flow passage and other flow passages.

Lubricant Delivery System

[00375] Regardless of the type of expansion device used in the system for lubricating the interface between an expansion cone and a tubular member during the expansion process, including, for example, expansion cones 5100, 5200, 5300, 5400, 5500, 5600, 5700, 5800, 5900, 6000, 6100, 6200, 6300, 6600, 6700, 6800, 6900, 7000 and 7100, lubricants utilized in the systems may be provided to the system in various manners. In an exemplary embodiment, lubricating fluids are provided to the internal flow passages or axial groove in expansion cones 5100, 5200, 5300, 5400, 5500, 5600, 5700, 5800, 5900, 6000, 6100, 6200, 6300, 6600, 6700, 6800, 6900, 7000 and 7100 using a supply of lubricating fluids provided adjacent to the front end 5100a, 5200a, 5300a, 5400a, 5500a, 5600a, 5700a,

5800a, 5900a, 6000a, 6100a, 6200a, 6300a, 6600a, 6700a, 6800a, 6900a, 7000a and 7100a, of the expansion cones 5100, 5200, 5300, 5400, 5500, 5600, 5700, 5800, 5900, 6000, 6100, 6200, 6300, 6600, 6700, 6800, 6900, 7000 and 7100. In another exemplary embodiment, lubricating fluids may provided to the internal flow passages or axial groove in expansion cones 5100, 5200, 5300, 5400, 5500, 5600, 5700, 5800, 5900, 6000, 6100, 6200, 6300, 6600, 6700, 6800, 6900, 7000 and 7100 using a supply of lubricating fluids provided adjacent to the rear end 5100a, 5200a, 5300a, 5400a, 5500a, 5600a, 5700a, 5800a, 5900a, 6000a, 6100a, 6200a, 6300a, 6600a, 6700a, 6800a, 6900a, 7000a and 7100a, of the expansion cones 5100, 5200, 5300, 5400, 5500, 5600, 5700, 5800, 5900, 6000, 6100, 6200, 6300, 6600, 6700, 6800, 6900, 7000 and 7100. Alternatively, the lubricating fluids may be injected into any internal flow passages in expansion cones 5100, 5200, 5300, 5400, 5500, 5600, 5700, 5800, 5900, 6000, 6100, 6200, 6300, 6600, 6700, 6800, 6900, 7000 and 7100 using a fluid conduit that is fluidicly coupled to the tapered ends of the expansion cones expansion cones 5100, 5200, 5300, 5400, 5500, 5600, 5700, 5800, 5900, 6000, 6100, 6200, 6300, 6600, 6700, 6800, 6900, 7000 and 7100.

[00376] Referring to Fig. 63, an embodiment of a system 7200 for lubricating the interface between an expansion cone and a tubular member during the expansion process will now be described. As illustrated in Fig. 63, an expansion cone 7202 includes a body 7204 that defines a centrally positioned longitudinal passage 7206, an internal annular recess 7208, an external annular recess 7210, longitudinal passages, 7212a and 7212b, fluidicly coupled between the internal and external annular recesses, longitudinal passages, 7214a and 7214b, fluidicly coupled to the external annular recess, radial passages, 7216a, 7216b, and 7216c, fluidicly coupled to the longitudinal passage 7214a, and radial passages, 7218a, 7218b, and 7218c, fluidicly coupled to the longitudinal passage 7214b, and includes a front end face 7220, a rear end face 7222, and a tapered external expansion surface 7224 including spaced apart external grooves, 7224a, 7224b, and 7224c, that are fluidicly coupled to the radial passages, 7214a, 7216a, 7214b, 7216b, 7214c, and 7216c, respectively. Spring-biased check valves, 7226a and 7226b, are received within, mate with, and are operably coupled to, the longitudinal passages, 7214a and 7214b, respectively, for controlling the flow of fluidic materials therethrough. A tubular member 7228 that defines a longitudinal passage 7228a and radial passages, 7228b and 7228c, that are fluidicly coupled to the internal annular recess 7208 of the expansion cone 7202 is received within, mates with, and is coupled to the centrally positioned longitudinal passage 7206 of the expansion cone.

[00377] In an exemplary embodiment, during operation of the system 7200, the expansion cone 7202 is positioned within, and displaced relative to, an expandable tubular member 7230 thereby radially expanding and plastically deforming the expandable tubular

member. In an exemplary embodiment, the expansion cone 7202 is displaced relative to the expandable tubular member 7230 by injecting a pressurized fluidic material 7232 into and through the passage 7228a of the tubular member 7228. As a result, the expansion cone 7202 is displaced in a direction 7233 relative to the expandable tubular member 7230. In an exemplary embodiment, the fluidic material 7232 includes one or more lubricant materials suitable for lubricating the interface between the expansion cone 7202 and the expandable tubular member 7230 during the radial expansion process. In particular, in an exemplary embodiment, the fluidic material 7232 is conveyed through the radial passages, 7228b and 7228c, of the tubular member 7228 into a annular chamber 7234 defined between the internal annular recess 7208 of the expansion cone 7202 and the tubular member 7228. If the operating pressure of the fluidic material 7232 exceeds a predetermined value, which will vary as a function of the operating characteristics of the check valves, 7226a and 7226b, the fluidic material is then conveyed through the longitudinal passages, 7212a and 7212b, into an annular chamber 7236 defined between the external annular recess 7210 of the expansion cone 7202 and the expandable tubular member 7230. The pressurized fluidic material 7232 is then conveyed into the external grooves, 7224a, 7224b, and 7224c, through the longitudinal passages, 7214a and 7214b, and the radial passages, 7216a, 7216b, 7216c, 7218a, 7218b, and 7218c, into the interface between the expansion cone 7202 and the expandable tubular member 7230.

[00378] In an exemplary embodiment, the rate of injection of the fluidic material 7232 into the external grooves, 7224a, 7224b, and 7224c, depends on the operating pressure of the fluidic material and the operating characteristics of the spring-biased check valves, 7226a and 7226b. In this manner, during the radial expansion process, the fluidic material 7232 may be controllably injected and metered into the interface between the tapered external expansion surface 7224 of the expansion cone 7202 and the expandable tubular member 7230 continuously during the radial expansion and plastic deformation of the tubular member. In an exemplary embodiment, the fluidic material 7232 may be injected into the external grooves, 7224a, 7224b, and 7224c only when required, or as desired. Thus, the trailing edge portion of the interface between the tapered external expansion surface 7224 of the expansion cone 7202 and the expandable tubular member 7230 may be provided with an increased supply of lubricant, thereby reducing the amount of force required to radially expand and plastically deform the expandable tubular member.

[00379] In an alternate embodiment, the spring-biased check valves, 7226a and 7226b, may be omitted, and/or used in combination with other types of flow metering devices such as, for example, passive flow control devices, active flow control devices, fixed orifices, and/or variable orifices.

[00380] Referring to Fig. 64, an embodiment of a system 7300 for lubricating the

interface between an expansion cone and a tubular member during the expansion process will now be described. As illustrated in Fig. 64, an expansion cone 7302 includes a body 7304 that defines a centrally positioned longitudinal passage 7306, an internal annular recess 7308, longitudinal passages, 7314a and 7314b, fluidicly coupled to the internal annular recess 7308, radial passages, 7316a, 7316b, and 7316c, fluidicly coupled to the longitudinal passage 7314a, and radial passages, 7318a, 7318b, and 7318c, fluidicly coupled to the longitudinal passage 7314b, and includes a front end face 7320, a rear end face 7322, and a tapered external expansion surface 7324 including spaced apart external grooves, 7324a, 7324b, and 7324c, that are fluidicly coupled to the radial passages, 7314a, 7316a, 7314b, 7316b, 7314c, and 7316c, respectively. A tubular member 7328 that defines a longitudinal passage 7328a and radial passages, 7328b and 7328c, that are fluidicly coupled to the internal annular recess 7308 of the expansion cone 7302, is received within, mates with, and is coupled to the centrally positioned longitudinal passage 7306 of the expansion cone. A tubular piston 7340 defines a passageway 7340a that receives, mates with and is slidably coupled to the tubular member 7328 and is received within, mates with and is slidably coupled to internal annular recess 7332, of the expansion cone.

[00381] In an exemplary embodiment, during operation of the system 7300, the expansion cone 7302 is positioned within, and displaced relative to, an expandable tubular member 7330 thereby radially expanding and plastically deforming the expandable tubular member. In an exemplary embodiment, the expansion cone 7302 is displaced relative to the expandable tubular member 7330 by injecting a pressurized fluidic material 7332 into and through the passage 7328a of the tubular member 7328. As a result, the expansion cone 7302 is displaced in a direction 7333 relative to the expandable tubular member 7330. In an exemplary embodiment, the fluidic material 7332 includes one or more lubricant materials suitable for lubricating the interface between the expansion cone 7302 and the expandable tubular member 7330 during the radial expansion process. In particular, in an exemplary embodiment, the fluidic material 7332 is conveyed through the radial passages, 7328b and 7328c, of the tubular member 7328, into an annular chamber 7336 defined between the external annular recess 7310 of the expansion cone 7302 and the expandable tubular member 7330 above tubular piston 7340. In an exemplary embodiment, a second fluidic material 7344 may be housed in the annular chamber 7336 below tubular piston 7342. In an exemplary embodiment, the second fluidic material 7344 includes one or more lubricant materials suitable for lubricating the interface between the expansion cone 7302 and the expandable tubular member 7330 during the radial expansion process. If the operating pressure of the fluidic material 7332 exceeds a predetermined value, which may vary as a function of the operating characteristics the tubular piston 7340, the fluidic material 7344 is then conveyed through the radial passages, 7328b and 7328c, into an annular chamber

7336 defined between the external annular recess 7310 of the expansion cone 7302 and the expandable tubular member 7330. In particular, if the operating pressure of the fluidic material 7332 exceeds a predetermined value, the tubular piston 7340 is displaced within the annular chamber 7336 thereby pumping the pressurized fluidic material 7344 into the external grooves, 7324a, 7324b, and 7324c, through the longitudinal passages, 7314a and 7314b, and the radial passages, 7316a, 7316b, 7316c, 7318a, 7318b, and 7318c, into the interface between the expansion cone 7302 and the expandable tubular member 7330.

[00382] In an exemplary embodiment, the rate of injection of the fluidic material 7344 into the external grooves, 7324a, 7324b, and 7324c, depends on the operating pressure of the fluidic material 7232 and the operating characteristics of the tubular piston 7340. The tubular piston 7340 pumps second fluidic material 7344 when the input pressure of the fluidic material 7332 exceeds a predetermined pressure limit, which may be a factor of diameter of the tubular member 7330 the length of the tubular member 7330 and the desired amount of lubricant to be dispensed. In this manner, during the radial expansion process, the fluidic material 7344 may be controllably injected and pumped into the interface between the tapered external expansion surface 7324 of the expansion cone 7302 and the expandable tubular member 7330 continuously during the radial expansion and plastic deformation of the tubular member. In an exemplary embodiment, the fluidic material 7332 may be injected into the external grooves, 7324a, 7324b, and 7324c only when required, or as desired. Thus, the trailing edge portion of the interface between the tapered external expansion surface 7324 of the expansion cone 7302 and the expandable tubular member 7330 may be provided with an increased supply of lubricant, thereby reducing the amount of force required to radially expand and plastically deform the expandable tubular member.

[00383] In an exemplary embodiment, the second fluidic material 7344 in the annular chamber 7336 below tubular piston 7340 may be preloaded into expansion cone 7300 prior to being used to expand tubular member 7330. Alternatively, the lubricant may be replenished by a lubrication source located in a remote location from expansion cone 7300.

[00384] Referring to Fig. 65, an embodiment of a system 7400 for lubricating the interface between an expansion cone and a tubular member during the expansion process will now be described. As illustrated in Fig. 65, an expansion cone 7402 includes a body 7404 that defines a centrally positioned longitudinal passage 7406, an internal annular recess 7408, an external annular recess 7410, longitudinal passages, 7412a and 7412b, fluidicly coupled between the internal and external annular recesses, longitudinal passages, 7414a and 7414b, fluidicly coupled to the external annular recess, radial passages, 7416a, 7416b, and 7416c, fluidicly coupled to the longitudinal passage 7414a, and radial passages, 7418a, 7418b, and 7418c, fluidicly coupled to the longitudinal passage 7414b, and includes a front end face 7420, a rear end face 7422, and a tapered external expansion surface 7424

including spaced apart external grooves, 7424a, 7424b, and 7424c, that are fluidicly coupled to the radial passages, 7414a, 7416a, 7414b, 7416b, 7414c, and 7416c, respectively. Spring-biased check valves, 7426a and 7426b, are received within, mate with, and are operably coupled to, the longitudinal passages, 7414a and 7414b, respectively, for controlling the flow of fluidic materials therethrough. A tubular member 7428 that defines a longitudinal passage 7428a and radial passages, 7428b and 7428c, that are fluidicly coupled to the internal annular recess 7408 of the expansion cone 7402 is received within, mates with, and is coupled to the centrally positioned longitudinal passage 7406 of the expansion cone. A tubular piston 7440 defines a passageway 7440a that receives, mates with and is slidably coupled to the tubular member 7428 and is received within, mates with and is slidably coupled to internal annular recess 7432 of the expansion cone 7400.

[00385] In an exemplary embodiment, during operation of the system 7400, the expansion cone 7402 is positioned within, and displaced relative to, an expandable tubular member 7430 thereby radially expanding and plastically deforming the expandable tubular member. In an exemplary embodiment, the expansion cone 7402 is displaced relative to the expandable tubular member 7430 by injecting a pressurized fluidic material 7432 into and through the passage 7428a of the tubular member 7428. As a result, the expansion cone 7402 is displaced in a direction 7433 relative to the expandable tubular member 7430. In an exemplary embodiment, the fluidic material 7432 includes one or more lubricant materials suitable for lubricating the interface between the expansion cone 7402 and the expandable tubular member 7430 during the radial expansion process. In particular, in an exemplary embodiment, the fluidic material 7432 is conveyed through the radial passages, 7428b and 7428c, of the tubular member 7428 into a annular chamber 7434 defined between the internal annular recess 7408 of the expansion cone 7402 and the tubular member 7428. In an exemplary embodiment, a second fluidic material 7444 may be housed in the annular chamber 7434 below tubular piston 7442 and in an annular chamber 7436 defined between the external annular recess 7410 of the expansion cone 7402 and the expandable tubular member 7430. In an exemplary embodiment, the fluidic material 7444 includes one or more lubricant materials suitable for lubricating the interface between the expansion cone 7402 and the expandable tubular member 7430 during the radial expansion process. If the operating pressure of the fluidic material 7432 exceeds a predetermined value, which will vary as a function of the operating characteristics of the check valves, 7426a and 7426b, and tubular piston 7440, the tubular piston is displaced within annular chamber 7434, thereby pumping the second fluidic material through the longitudinal passages, 7412a and 7412b, into the annular chamber 7436. The pressurized fluidic material 7444 is then conveyed into the external grooves, 7424a, 7424b, and 7424c, through the longitudinal passages, 7414a and 7414b, and the radial passages, 7416a, 7416b, 7416c, 7418a, 7418b,

and 7418c, into the interface between the expansion cone 7402 and the expandable tubular member 7430.

[00386] In an exemplary embodiment, the rate of injection of the fluidic material 7444 into the external grooves, 7424a, 7424b, and 7424c, depends on the operating pressure of the fluidic material and the operating characteristics of the spring-biased check valves, 7426a and 7426b, and tubular piston 7440. In this manner, during the radial expansion process, the fluidic material 7444 may be controllably injected and metered into the interface between the tapered external expansion surface 7424 of the expansion cone 7402 and the expandable tubular member 7430 continuously during the radial expansion and plastic deformation of the tubular member. In an exemplary embodiment, the fluidic material 7444 may be injected into the external grooves, 7424a, 7424b, and 7424c only when required, or as desired. Thus, the trailing edge portion of the interface between the tapered external expansion surface 7424 of the expansion cone 7402 and the expandable tubular member 7430 may be provided with an increased supply of lubricant, thereby reducing the amount of force required to radially expand and plastically deform the expandable tubular member.

[00387] In an embodiment, valves 7426a and 7426b, permits lubricant flow when the input pressure of the fluidic material 7432 exceeds a predetermined pressure limit, which may be a factor of diameter of the tubular member, the length of the tubular member and the desired amount of lubricant to be dispensed. In an embodiment, tubular piston 7440 pumps the fluidic material 7444 into the annular chamber 7736, based on the input pressure of the fluidic material 7432, such as, for example, when the input pressure of the fluidic material 7444 exceeds a predetermined pressure limit, which may be a factor of diameter of the tubular member 7430, the length of the tubular member 7430 and the desired amount of lubricant to be injected.

[00388] In an exemplary embodiment, the second fluidic material 7444 in annular chambers, 7434 and 7436 below tubular piston 7440 may be preloaded into expansion cone 7400 prior to being used to expand tubular member 7402. Alternatively, the lubricant may be replenished by a lubrication source located in a remote location from expansion cone 7400.

[00389] In an alternate embodiment, the tubular piston 7440 and spring-biased check valves, 7426a and 7426b, may be omitted, and/or used in combination with other types of flow metering devices such as, for example, passive flow control devices, active flow control devices, fixed orifices, and/or variable orifices.

[00390] Referring to Fig. 66, an embodiment of a system 7500 for lubricating the interface between an expansion cone and a tubular member during the expansion process will now be described. As illustrated in Fig. 66, an expansion cone 7502 includes a body 7504 that defines a centrally positioned longitudinal passage 7506, an internal annular recess 7508, an external annular recess 7510, longitudinal passages, 7512a and 7512b,

fluidicly coupled between the internal and external annular recesses, longitudinal passages, 7514a and 7514b, fluidicly coupled to the external annular recess, radial passages, 7516a, 7516b, and 7516c, fluidicly coupled to the longitudinal passage 7514a, and radial passages, 7518a, 7518b, and 7518c, fluidicly coupled to the longitudinal passage 7514b, and includes a front end face 7520, a rear end face 7522, and a tapered external expansion surface 7524 including spaced apart external grooves, 7524a, 7524b, and 7524c, that are fluidicly coupled to the radial passages, 7514a, 7516a, 7514b, 7516b, 7514c, and 7516c, respectively. Spring-biased check valves, 7526a and 7526b, are received within, mate with, and are operably coupled to, the longitudinal passages, 7514a and 7514b, respectively, for controlling the flow of fluidic materials therethrough. A tubular member 7528 that defines a longitudinal passage 7528a and radial passages, 7528b and 7528c, that are fluidicly coupled to the internal annular recess 7508 of the expansion cone 7502 is received within, mates with, and is coupled to the centrally positioned longitudinal passage 7506 of the expansion cone. A conventional pressure enhancer 7550 is received within, mates with and is slidably coupled to external annular recess 7510, of the expansion cone.

[00391] In an exemplary embodiment, during operation of the system 7500, the expansion cone 7502 is positioned within, and displaced relative to, an expandable tubular member 7530 thereby radially expanding and plastically deforming the expandable tubular member. In an exemplary embodiment, the expansion cone 7502 is displaced relative to the expandable tubular member 7530 by injecting a pressurized fluidic material 7532 into and through the passage 7528a of the tubular member 7528. As a result, the expansion cone 7502 is displaced in a direction 7533 relative to the expandable tubular member 7530. In an exemplary embodiment, the fluidic material 7532 includes one or more lubricant materials suitable for lubricating the interface between the expansion cone 7502 and the expandable tubular member 7530 during the radial expansion process. In particular, in an exemplary embodiment, the fluidic material 7532 is conveyed through the radial passages, 7528b and 7528c, of the tubular member 7528 into a annular chamber 7534 defined between the internal annular recess 7508 of the expansion cone 7502 and the tubular member 7528. The pressure enhancer 7550 increases the pressure on the fluidic material. If the operating pressure of the fluidic material 7532 exceeds a predetermined value, which will vary as a function of the operating characteristics of the check valves, 7526a and 7526b, the fluidic material is then conveyed through the longitudinal passages, 7512a and 7512b, into an annular chamber 7536 defined between the external annular recess 7510 of the expansion cone 7502 and the expandable tubular member 7530. The pressurized fluidic material 7532 is then conveyed into the external grooves, 7524a, 7524b, and 7524c, through the longitudinal passages, 7514a and 7514b, and the radial passages, 7516a, 7516b, 7516c, 7518a, 7518b, and 7518c, into the interface between the expansion cone 7502 and the

expandable tubular member 7530.

[00392] In an exemplary embodiment, the rate of injection of the fluidic material 7532 into the external grooves, 7524a, 7524b, and 7524c, depends on the operating pressure of the fluidic material and the operating characteristics of the pressure enhancer 7550 and of the spring-biased check valves, 7526a and 7526b. In this manner, during the radial expansion process, the fluidic material 7532 may be controllably injected and metered into the interface between the tapered external expansion surface 7524 of the expansion cone 7502 and the expandable tubular member 7530 continuously during the radial expansion and plastic deformation of the tubular member. In an exemplary embodiment, the fluidic material 7532 may be injected into the external grooves, 7524a, 7524b, and 7524c only when required, or as desired. Thus, the trailing edge portion of the interface between the tapered external expansion surface 7524 of the expansion cone 7502 and the expandable tubular member 7530 may be provided with an increased supply of lubricant, thereby reducing the amount of force required to radially expand and plastically deform the expandable tubular member.

[00393] In an alternate embodiment, the spring-biased check valves, 7526a and 7526b, may be omitted, and/or used in combination with other types of flow metering devices such as, for example, passive flow control devices, active flow control devices, fixed orifices, and/or variable orifices. In an alternate embodiment, the pressure enhancer 7550, which any type of pressure enhancing device, such as, for example, a piston or a diaphragm, may be omitted, and/or used in combination with other types of flow enhancing devices or pressure increasing devices, such as, for example, passive flow control devices, active flow control devices, fixed orifices, and/or variable orifices, such as, for example, a high-pressure lubricator.

[00394] Referring to Fig. 67, an embodiment of a system 7600 for lubricating the interface between an expansion cone and a tubular member during the expansion process will now be described. As illustrated in Fig. 67, an expansion cone 7602 includes a body 7604 that defines a centrally positioned longitudinal passage 7606, an internal annular recess 7608, an external annular recess 7610, longitudinal passages, 7612a and 7612b, fluidicly coupled between the internal and external annular recesses, longitudinal passages, 7614a and 7614b, fluidicly coupled to the external annular recess, radial passages, 7616a, 7616b, and 7616c, fluidicly coupled to the longitudinal passage 7614a, and radial passages, 7618a, 7618b, and 7618c, fluidicly coupled to the longitudinal passage 7614b, and includes a front end face 7620, a rear end face 7622, and a tapered external expansion surface 7624 including spaced apart external grooves, 7624a, 7624b, and 7624c, that are fluidicly coupled to the radial passages, 7614a, 7616a, 7614b, 7616b, 7614c, and 7616c, respectively. Spring-biased check valves, 7626a and 7626b, are received within, mate with, and are

operably coupled to, the longitudinal passages, 7614a and 7614b, respectively, for controlling the flow of fluidic materials therethrough. A tubular member 7628 that defines a longitudinal passage 7628a and radial passages, 7628b and 7628c, that are fluidicly coupled to the internal annular recess 7608 of the expansion cone 7602 is received within, mates with, and is coupled to the centrally positioned longitudinal passage 7606 of the expansion cone. A tubular piston 7640 defines a passageway 7642 that receives, mates with and is slidably coupled to the tubular member 7628 and is received within, mates with and is slidably coupled to internal annular recess 7632, of the expansion cone. A conventional pressure enhancer 7650 is received within, mates with and is slidably coupled to external annular recess 7610, of the expansion cone 7630.

[00395] In an exemplary embodiment, during operation of the system 7600, the expansion cone 7602 is positioned within, and displaced relative to, an expandable tubular member 7630 thereby radially expanding and plastically deforming the expandable tubular member. In an exemplary embodiment, the expansion cone 7602 is displaced relative to the expandable tubular member 7630 by injecting a pressurized fluidic material 7632 into and through the passage 7628a of the tubular member 7628. As a result, the expansion cone 7602 is displaced in a direction 7633 relative to the expandable tubular member 7630. In an exemplary embodiment, the fluidic material 7632 includes one or more lubricant materials suitable for lubricating the interface between the expansion cone 7602 and the expandable tubular member 7630 during the radial expansion process. In particular, in an exemplary embodiment, the fluidic material 7632 is conveyed through the radial passages, 7628b and 7628c, of the tubular member 7628 into a annular chamber 7634 defined between the internal annular recess 7608 of the expansion cone 7602 and the tubular member 7628. In an exemplary embodiment, a second fluidic material 7644 may be housed in the annular chamber 7634 below tubular piston 7642 and in an annular chamber 7636 defined between the external annular recess 7610 of the expansion cone 7602 and the expandable tubular member 7630. In an exemplary embodiment, the fluidic material 7644 includes one or more lubricant materials suitable for lubricating the interface between the expansion cone 7602 and the expandable tubular member 7630 during the radial expansion process. If the operating pressure of the fluidic material 7632 exceeds a predetermined value, which will vary as a function of the operating characteristics of the check valves, 7626a and 7626b, and tubular piston 7640, the tubular piston is displaced within annular chamber 7634, thereby pumping the second fluidic material through the longitudinal passages, 7612a and 7612b, into the annular chamber 7636. The pressure enhancer 7650 increases the pressure on the second fluidic material 7644. The pressurized fluidic material 7644 is then conveyed into the external grooves, 7624a, 7624b, and 7624c, through the longitudinal passages, 7614a and 7614b, and the radial passages, 7616a, 7616b, 7616c, 7618a, 7618b, and

7618c, into the interface between the expansion cone 7602 and the expandable tubular member 7630.

[00396] In an exemplary embodiment, the rate of injection of the fluidic material 7644 into the external grooves, 7624a, 7624b, and 7624c, depends on the operating pressure of the fluidic material and the operating characteristics of the spring-biased check valves, 7626a and 7626b, tubular piston 7640 and pressure enhancer 7650 . In this manner, during the radial expansion process, the fluidic material 7644 may be controllably injected and metered into the interface between the tapered external expansion surface 7624 of the expansion cone 7602 and the expandable tubular member 7630 continuously during the radial expansion and plastic deformation of the tubular member. In an exemplary embodiment, the fluidic material 7644 may be injected into the external grooves, 7624a, 7624b, and 7624c only when required, or as desired. Thus, the trailing edge portion of the interface between the tapered external expansion surface 7624 of the expansion cone 7602 and the expandable tubular member 7630 may be provided with an increased supply of lubricant, thereby reducing the amount of force required to radially expand and plastically deform the expandable tubular member.

[00397] In an embodiment, valves 7626a and 7626b, permits lubricant flow when the input pressure of the fluidic material 7632 exceeds a predetermined pressure limit, which may be a factor of diameter of the tubular member, the length of the tubular member and the desired amount of lubricant to be dispensed. In an embodiment, tubular piston 7640 pumps the fluidic material 7644 into the annular chamber 7636, based on the input pressure of the fluidic material 7632, such as, for example, when the input pressure of the fluidic material 7644 exceeds a predetermined pressure limit, which may be a factor of diameter of the tubular member 7630, the length of the tubular member 7630 and the desired amount of lubricant to be injected.

[00398] In an exemplary embodiment, the second fluidic material 7644 in an annular chamber 7636 below tubular piston 7640 may be preloaded into expansion cone 7600 prior to being used to expand tubular member 7602. Alternatively, the lubricant may be replenished by a lubrication source located in a remote location from expansion cone 7600.

[00399] In an alternate embodiment, the tubular piston 7640 and spring-biased check valves, 7626a and 7626b, may be omitted, and/or used in combination with other types of flow metering devices such as, for example, passive flow control devices, active flow control devices, fixed orifices, and/or variable orifices. In an alternate embodiment, the pressure enhancer 7550, which any type of pressure enhancing device, such as, for example, a piston or a diaphragm, may be omitted, and/or used in combination with other types of flow enhancing devices or pressure increasing devices, such as, for example, passive flow control devices, active flow control devices, fixed orifices, and/or variable orifices, such as,

for example, a high-pressure lubricator.

[00400] Referring to Fig. 68, an embodiment of a system 7700 for lubricating the interface between an expansion cone and a tubular member during the expansion process will now be described. As illustrated in Fig. 68, an expansion cone 7702 includes a body 7704 that defines a centrally positioned longitudinal passage 7706, an internal annular recess 7708, an internal annular recess 7709, an external annular recess 7710, longitudinal passages, 7712a and 7712b, fluidicly coupled between the internal and external annular recesses, longitudinal passages, 7714a and 7714b, fluidicly coupled to the external annular recess, radial passages, 7716a, 7716b, and 7716c, fluidicly coupled to the longitudinal passage 7714a, and radial passages, 7718a, 7718b, and 7718c, fluidicly coupled to the longitudinal passage 7714b, and includes a front end face 7720, a rear end face 7722, and a tapered external expansion surface 7724 including spaced apart external grooves, 7724a, 7724b, and 7724c, that are fluidicly coupled to the radial passages, 7714a, 7716a, 7714b, 7716b, 7714c, and 7716c, respectively. Spring-biased check valves, 7726a and 7726b, are received within, mate with, and are operably coupled to, the longitudinal passages, 7714a and 7714b, respectively, for controlling the flow of fluidic materials therethrough. A tubular member 7728 that defines a longitudinal passage 7728a and radial passages, 7728b and 7728c, that are fluidicly coupled to the internal annular recess 7708 of the expansion cone 7702 is received within, mates with, and is coupled to the centrally positioned longitudinal passage 7706 of the expansion cone. A tubular piston 7740 defines a passageway 7740a that receives, mates with and is slidably coupled to the tubular member 7728 and is received within, mates with and is slidably coupled to internal annular recess 7732, of the expansion cone. A capacitor bank 7750 is received within the internal annular chamber 7709 and is electrically coupled to power source 7760 through connectors 7756. Electrodes 7754a and 7754b are received within external annular recess 7732 and are electrically coupled to capacitor bank 7750 through connectors 7758.

[00401] In an exemplary embodiment, during operation of the system 7700, the expansion cone 7702 is positioned within, and displaced relative to, an expandable tubular member 7730 thereby radially expanding and plastically deforming the expandable tubular member. In an exemplary embodiment, the expansion cone 7702 is displaced relative to the expandable tubular member 7730 by injecting a pressurized fluidic material 7732 into and through the passage 7728a of the tubular member 7728. As a result, the expansion cone 7702 is displaced in a direction 7733 relative to the expandable tubular member 7730. In an exemplary embodiment, the fluidic material 7732 includes one or more lubricant materials suitable for lubricating the interface between the expansion cone 7702 and the expandable tubular member 7730 during the radial expansion process. In particular, in an exemplary embodiment, the fluidic material 7732 is conveyed through the radial passages, 7728b and

7728c, of the tubular member 7728 into a annular chamber 7734 defined between the internal annular recess 7708 of the expansion cone 7702 and the tubular member 7728. In an exemplary embodiment, a second fluidic material 7744 may be housed in the annular chamber 7734 below tubular piston 7742 and in an annular chamber 7736 defined between the external annular recess 7710 of the expansion cone 7702 and the expandable tubular member 7730. In an exemplary embodiment, the fluidic material 7744 includes one or more lubricant materials suitable for lubricating the interface between the expansion cone 7702 and the expandable tubular member 7730 during the radial expansion process. If the operating pressure of the fluidic material 7732 exceeds a predetermined value, which will vary as a function of the operating characteristics of the check valves, 7726a and 7726b, and tubular piston 7740, the tubular piston is displaced within annular chamber 7734, thereby pumping the second fluidic material through the longitudinal passages, 7712a and 7712b, into the annular chamber 7736. The pressurized fluidic material 7744 is then conveyed into the external grooves, 7724a, 7724b, and 7724c, through the longitudinal passages, 7714a and 7714b, and the radial passages, 7716a, 7716b, 7716c, 7718a, 7718b, and 7718c, into the interface between the expansion cone 7702 and the expandable tubular member 7730. In an embodiment, the pressure on the fluidic material 7744 in annular recess 7736 may be increased by the introduction of an electric pulse into the fluidic material 7744 through electrodes, 7754a and 7754b by the discharging the capacitor bank 7750 to trigger a high-pressure gaseous expansion within the lubricant in external annular recess 7732 by means of an electric discharge.

[00402] In an exemplary embodiment, the rate of injection of the fluidic material 7744 into the external grooves, 7724a, 7724b, and 7724c, depends on the operating pressure of the fluidic material and the operating characteristics of the spring-biased check valves, 7726a and 7726b, and tubular piston 7740. In this manner, during the radial expansion process, the fluidic material 7744 may be controllably injected and metered into the interface between the tapered external expansion surface 7724 of the expansion cone 7702 and the expandable tubular member 7730 continuously during the radial expansion and plastic deformation of the tubular member. In an exemplary embodiment, the fluidic material 7744 may be injected into the external grooves, 7724a, 7724b, and 7724c only when required, or as desired. Thus, the trailing edge portion of the interface between the tapered external expansion surface 7724 of the expansion cone 7702 and the expandable tubular member 7730 may be provided with an increased supply of lubricant, thereby reducing the amount of force required to radially expand and plastically deform the expandable tubular member.

[00403] In an embodiment, valves 7726a and 7726b, permits lubricant flow when the input pressure of the fluidic material 7732 exceeds a predetermined pressure limit, which may be a factor of diameter of the tubular member, the length of the tubular member and the

desired amount of lubricant to be dispensed. In an embodiment, tubular piston 7740 pumps the fluidic material 7744 into the annular chamber 7736, based on the input pressure of the fluidic material 7732, such as, for example, when the input pressure of the fluidic material 7744 exceeds a predetermined pressure limit, which may be a factor of diameter of the tubular member 7730, the length of the tubular member 7730 and the desired amount of lubricant to be injected.

[00404] In an exemplary embodiment, the second fluidic material 7744 in an annular chamber 7736 below tubular piston 7740 may be preloaded into expansion cone 7700 prior to being used to expand tubular member 7702. Alternatively, the lubricant may be replenished by a lubrication source located in a remote location from expansion cone 7700.

[00405] In an alternate embodiment, the tubular piston 7740 and spring-biased check valves, 7726a and 7726b, may be omitted, and/or used in combination with other types of flow metering devices such as, for example, passive flow control devices, active flow control devices, fixed orifices, and/or variable orifices.

[00406] In an exemplary embodiment, the introduction of electrodes 7754a and 7754b that are electrically coupled via connectors 7758 to bank of capacitor 7750 to trigger a high-pressure gaseous expansion within an enclosed volume of lubricant in annular chamber 7736 when bank of capacitors 7750 discharge, which in turn, may increase the lubricant pressure. The discharge expansion may create a pressure impulse allowing more lubricant to flow between the expansion cone 7700 and tubular member 7730, thereby reducing the friction. The expansion may create a pressure impulse in annular recess 7736 of approximately 15ksi, allowing more lubricant to flow between expansion cone 7700 and tubular member 7702 and thereby reducing the friction, which may reduce the working pressure behind the expansion cone 7700.

[00407] A discharge may occur between electrodes 7754a and 7754b in the lubricant stored in external annular recess 7732 that acts as a dielectric when capacitor bank 7750 discharge current through connectors 7756 to electrodes 7754a and 7754b. When the lubricant dielectric between the electrodes 7754a and 7754b breaks down, a high temperature arc is created which vaporizes some of the dielectric. Due to the incompressibility of fluids, the vaporization may create a pulse of pressure, which complements the existing fluid pressure.

[00408] The following three properties may be considered when determining the properties of a system for lubricating the interface between an expansion cone and a tubular member implementing a mechanism to trigger a high-pressure gaseous expansion: thermodynamic properties, electric properties, and deformation properties of the tubular member during the expansion process.

[00409] Regarding thermodynamic properties, due to the non-ideal nature of a vaporized dielectric medium, the following equations may be utilized to determining the properties of a system for lubricating the interface between expansion cone 7700 and a tubular member 7702 during the expansion process implementing a mechanism to trigger a high-pressure gaseous expansion. Van der Waals equation may be manipulated to express pressure as a function of the ratio of dielectric medium density, average molar mass, and the dielectric's boiling point as follows:

$$\left[P + a\left(\frac{n}{V}\right)^2\right](V - nb) = nRT$$

where:

P – Pressure [psi]

V – Volume of Vaporized Lubricant

T – Temperature [K]

n – Moles of Lubricant [mols]

R – 1.206 [L-psi/K-mol]

a – Experimental Proportionality Constant

b – Experimental Constant Relating to Molecular Volume

$$P = \frac{RT_b}{(\frac{M}{\rho}) - b} - a\left(\frac{\rho}{M}\right)^2$$

where:

P – Pressure [psi]

T_b – Lubricant's Boiling Point [°K]

M – Av. Lubricant Molar Mass

ρ – Lubricant Density

R – 1.206 [L-psi/K-mol]

a – Experimental Proportionality Constant

b – Experimental Constant Relating to Molecular Volume

Since the volume of the external annular recess 7732 is not well defined, the following constraints may be used. It is assumed that the vaporization takes place at about the boiling point of the dielectric, because the addition of the heat of vaporization does not change the temperature. However, increases beyond this temperature may have no negative effect on vaporization. Furthermore, there is no common direct mathematic relationship between the discharge energy and the pressure created by the vaporization. Molar mass of the dielectric may need to be calculated experimentally or mathematically if all the components of the

dielectric medium are known. The constants 'a' and 'b' may be experimentally determined or may be available in engineering tables based on the choice of lubricant.

[00410] The effective discharge energy ($E_{effective}$) of back of capacitor 7750 should be greater than the energy required to vaporize 'm' grams of the lubricant as exhibited in the following equation:

$$E_{effective} = \tfrac{1}{2} k_e C V_b^2 > mL_v + mL_s T \quad (13)$$

$$T = T_b - T_i \,[K] \quad (14)$$

where:

$E_{eff.}$ – Effective Lubricant Energy [J]

k_e – Energy Efficiency Factor

C – Capacitance

V_b– Breakdown Voltage

m – Mass of Vaporized Lubricant

L_v – Heat of Vaporization [J/gm]

L_s – Specific Heat [J/gm-K]

T_b – Lubricant's Boiling Point [K]

T_i – Dielectric Initial Temperature [K] T – T_b - T_i [K]

The effective discharge energy ($E_{effective}$) of back of capacitor 7750 is proportionately related to the calculated discharge energy of back of capacitor 7750 by an experimentally determined an "energy efficiency factor". The mass 'm' of vaporized lubricant will depend on the geometry of the electrodes and of the discharge volume.

[00411] Regarding electric properties, the discharge of electricity takes place when the potential across the electrodes equals the breakdown voltage. Breakdown voltage for two electrodes 7754a and 7754b can be calculated from the lubricant's dielectric strength using the following equations:

$$V_b = dE_{ds} \quad (15)$$

where:

V_b – Breakdown Voltage

d – Distance Between Electrodes [mm]

E_{ds} – Dielectric Strength [kV/mm]

In general, oils have high dielectric strengths, on the order of about 10-50 kV/mm. In an exemplary embodiment, a dielectric strength on the low end of that range may be desired.

[00412] An expression for the relation between current and total resistance is as follows:

$$V_b = IR > \sqrt{\frac{2m(L_v + L_s T)}{k_e C}} \qquad (16)$$

where:

V_b – Breakdown Voltage
I – Line Current
m – Mass of Vaporized Dielectric
R – System Resistance
L_v – Heat of Vaporization [J/gm]
L_s – Specific Heat [J/gm-K]
T – T_b - T_i [K]
k_e – Energy Efficiency Factor
C – Capacitance

$$R = R_{internal} + R_{design} + Z_{line} \qquad (17)$$

where:

R – System Resistance
$R_{int.}$ – Internal Resistance
R_{design} – Design Resistance
Z_{line} – Line Impedance

The resistance consists of several components, internal resistance of bank of capacitors 7752, resistance added by the designer, and line impedance. Line impedance may play an important role since the system will not be in steady state and may need to be determined empirically.

[00413] The equation for the effective discharge energy $E_{effective}$ of bank of capacitors 7752 suggests that minimizing the specific heat and the heat of vaporization may result in lower required discharge energy. Synthetic oils, which generally have higher heats of vaporization, generally have film strengths exceeding 3000 psi. Mineral-based oils have film strengths of about 400 psi. However, neither synthetic oils nor mineral based oils may be sufficient for the expected pressures of 10ksi-15ksi. It seems that a hard lubricant with a higher tolerance for pressure, such as graphite or molybdenum disulfide, may work better. However, the heat of vaporization of a hard lubricant may be significantly higher than that of a liquid lubricant. Also, the electrodes 7754a and 7754b and the surrounding liquid dielectric may be insulated to prevent any permanent dielectric breakdown in such a hard

lubricants. The use of a system for lubricating the interface between an expansion cone and a tubular member during the expansion process implementing a mechanism to trigger a high-pressure gaseous expansion may be also advantageous because it allows more flexibility in the choice of the dielectric medium.

[00414] An important aspect of the a system for lubricating the interface between an expansion cone and a tubular member during the expansion process implementing a mechanism to trigger a high-pressure gaseous expansion design is the frequency of the discharges. Assuming, for the purpose of analysis that the breakdown voltage across the electrodes 7754a and 7754b is reached at around *t*=RC sec, frequency can be easily expressed by thy following equation:

$$\lambda = \frac{1}{RC} \qquad (18)$$

where:

R – System Resistance

λ – Discharge Frequency [Hz]

C – Capacitance

Estimating that the frequency of the discharges will be at least 3 Hz, the lifetime rating of the capacitor bank 7750 should be as high.

[00415] Since the expansion cone may be used at considerable depths, it is desirable that capacitor bank 7750 be located as close to the electrodes 7754a and 7754b as possible. In one embodiment, it is anticipated that any commercial capacitor for high-power pulsing applications that uses charging voltages in the tens of kV, can retain several kJ of energy, and is able to deliver current on the order of 100 kA may be used in capacitor bank 7750. In addition, the selected capacitor should be able to tolerate significant voltage reversal. In an exemplary embodiment, high power capacitors, such as those manufactured by Passoni Villa that have built in switches, may be used to achieve more control of the discharge frequency.

[00416] In an exemplary embodiment, the following of manufacturers may supply capacitors suitable for capacitor bank 7750, include the following:

Passoni Villa (www.passoni-villa.com (Capacitors));

Aerovox (www.aerovox.com (Capacitors));

Richardson Electronics (www.industrial.rell.com (Ignitrons));

Darrah Electric (www.darrahelectric.com (Power Semiconductors));

Magnet-Physik (www.magnet-physik.de (EMF Forming)) and

Magneform (www.magneform.com (EMF Forming)).

In an exemplary embodiment, capacitor bank 7750 may include one capacitor or a plurality of capacitors.

[00417] In an exemplary embodiment, a solid-state amplifier located near the capacitor bank 7750 may be utilized instead of a high-voltage transformer due to size considerations. Example manufacturers of such devices are as follows:

Richardson Electronics (www.industrial.rell.com (Ignitrons));

Darrah Electric (www.darrahelectric.com (Power Semiconductors));

Magnet-Physik (www.magnet-physik.de (EMF Forming)); and

Magneform (www.magneform.com (EMF Forming))..

[00418] Regarding the expandable tubular member deformation characteristics, the work done on tubular member 7702 by the shockwave created by the electric discharge may be constrained to be less than the amount of work required to deform the tube. The work done on the tubular member 7702 can be calculated using the tubular member 7702 material properties and its cylindrical geometry. The expression for specific work of deformation is as follows:

$$a_s = \frac{B}{1+m_m} E^{(1+m_m)} \qquad (19)$$

where:

a_s – Specific Work of Deformation

E – Deformation Intensity

B, m_m – Mechanical characteristics of tubular member 7702

[00419] The constant m_m, true strain, is defined the following equation:

$$\mathrm{m_m} = \mathrm{e_n} = \ln(1 + \frac{\Delta \mathrm{ln}}{\mathrm{l_0}}) \qquad (20)$$

where:

m_m – True Strain

$\Delta l_n / l_0$ – Elongation

In an exemplary embodiment, $\Delta l_n / l_0$ is the elongation of tubular member 7702, such as for example, in the case of En-80 steel, with $\Delta l_n / l_0 = 0.20$, $m_m = 0.182$.

[00420] The mechanical constant B is defined by the following equation.

$$B = \frac{\mathrm{E}^{\mathrm{m_m}}}{\mathrm{e_n}^{\mathrm{m_m}}} \sigma_b \qquad (21)$$

where:

$\mathrm{E} - \frac{r}{r_0} - 1$

m_m – True Strain

e_n – $e_n = m_m$

σ_b – Yield Strength

[00421] For a cylindrical geometry such as that of tubular member 7702, E is defined the following equation:

$$E = \frac{r}{r_0} - 1 \qquad (22)$$

where:

E – Deformation Intensity

r_0 – Original Radius

r – Final Radius

The radius referred to is the inner radius of the tubular member 7702.

[00422] The total work of deformation is a function of the specific work of deformation and the volume of the tubular member 7702 material deformed. The work done by the discharge on the tubular member must be no greater than the work required to expand the tubular member 7702 to its final radius and is defined as follows:

$$W_D < a_s V_w \qquad (23)$$

where:

a_s – Specific Work of Deformation

V_w – Volume of Deformed Material

W_D – Work Due to Discharge

[00423] An expression relating the maximum amount of work may be constructed by assuming a discharge volume of axial length β, and an outer radius r_0 (the outer radius being equal to the inner radius of the unexpanded tubular member 7702). The final outer radius will be designated by r. The equation defining the volume of deformed material, V_w, is as follows:

$$V_w = 2\beta(r^2 - r_0^2) \qquad (24)$$

where:

β – Axial Length of Discharge Volume

r – Final Radius

r_0 – Original Radius

V_w – Volume of Deformed Material

[00424] In an exemplary embodiment, using the equations specified above for a tubular member 7702 that expands from a 4.77" inside diameter to a 5.68" inside diameter, hypothetically the deformation intensity (E) is 0.191, assuming that the axial length of discharge volume (β) is 0.04m and produces a volume of deformation material (V_w) of 0.005809 m^3 and true strain (m_m) of 0.182. Note that the yield strength (σ_b) range for En-80

steel tubes is approximately 48.26×10^7 N/m^2 (70 ksi) to 65.50×10^7 N/m^2 (95 ksi) and mechanical constant (B) is found to range from 48.69×10^7 N/m^2 to 66.08×10^7 N/m^2. Therefore, the specific work (a_s) of deformation ranges from 5.82×10^7 N/m^2 to 7.90×10^7 N/m^2. For this particular volume and radial expansion, the amount of work required to expand the tubular member 7702 is on the order of 460 kJ to 340 kJ. Hence, the work done on the tubular member 7702 due to the discharge may not exceed 340 kJ. However, the expected energy of the discharge is far lower. The pressure produced by the discharge may also be limited. The yield strength of En-80 steel is 70-95ksi. The pressure produced by the discharge can therefore not exceed 70ksi. Again, the expected maximum pressure due to the discharge will be approximately 15ksi. However, should the stated constraints be exceeded, the results would be unpredictable, and control over the process could be lost.

[00425] In an exemplary embodiment, an apparatus for testing a system for lubricating the interface between an expansion cone and a tubular member implementing a mechanism to trigger a high-pressure gaseous expansion during the expansion process may consider the following: (1) the determination of the specific capacitances of capacitor bank 7750, system resistances and impedances, and voltage required at power source 7760 for implementation may be found experimentally; and (2) the process values for a given lubricant may be determined by utilizing a discharge volume with piezoelectric sensors. Piezoelectric sensors are small, may withstand extremely high pressures, and produce electric outputs that are easily digitized and quantified for analysis. There are also several possible ways to regulate the power at power source 7760 in a testing apparatus, including for example, regulation of system resistance using potentiometers as an effective way to regulate the discharge power. The capacitor bank 7750 may also be designed to enable quick removal or addition of capacitors. A digital oscilloscope may be connected to the transmission line via a voltage divider to monitor system voltage. Finally, the current may be measured with a Rogowski coil, which uses the Hall effect to measure high currents.

[00426] Referring to Fig. 69, an embodiment of a system 7800 for lubricating the interface between an expansion cone and a tubular member during the expansion process will now be described. As illustrated in Fig. 69, an expansion cone 7802 includes a body 7804 that defines a centrally positioned longitudinal passage 7806, an internal annular recess 7808, an external annular recess 7810, longitudinal passages, 7812a and 7812b, fluidicly coupled between the internal and external annular recesses, longitudinal passages, 7814a and 7814b, fluidicly coupled to the external annular recess, radial passages, 7816a, 7816b, and 7816c, fluidicly coupled to the longitudinal passage 7814a, and radial passages, 7818a, 7818b, and 7818c, fluidicly coupled to the longitudinal passage 7814b, and includes a front end face 7820, a rear end face 7822, and a tapered external expansion surface 7824 including spaced apart external grooves, 7824a, 7824b, and 7824c, that are fluidicly coupled

to the radial passages, 7814a, 7816a, 7814b, 7816b, 7814c, and 7816c, respectively. Spring-biased check valves, 7826a and 7826b, are received within, mate with, and are operably coupled to, the longitudinal passages, 7814a and 7814b, respectively, for controlling the flow of fluidic materials therethrough. A tubular member 7828 that defines a longitudinal passage 7828a and radial passages, 7828b and 7828c, that are fluidicly coupled to the internal annular recess 7808 of the expansion cone 7802 is received within, mates with, and is coupled to the centrally positioned longitudinal passage 7806 of the expansion cone. A tubular piston 7840 defines a passageway 7840a that receives, mates with and is slidably coupled to the tubular member 7828 and is received within, mates with and is slidably coupled to internal annular recess 7732, of the expansion cone. A magnetic coil 7854 is received within external annular recess 7752 and is electrically coupled to power source 7860 via connectors, 7756a and 7756b.

[00427] In an exemplary embodiment, during operation of the system 7800, the expansion cone 7802 is positioned within, and displaced relative to, an expandable tubular member 7830 thereby radially expanding and plastically deforming the expandable tubular member. In an exemplary embodiment, the expansion cone 7802 is displaced relative to the expandable tubular member 7830 by injecting a pressurized fluidic material 7832 into and through the passage 7828a of the tubular member 7828. As a result, the expansion cone 7802 is displaced in a direction 7833 relative to the expandable tubular member 7830. In an exemplary embodiment, the fluidic material 7832 includes one or more lubricant materials suitable for lubricating the interface between the expansion cone 7802 and the expandable tubular member 7830 during the radial expansion process. In particular, in an exemplary embodiment, the fluidic material 7832 is conveyed through the radial passages, 7828b and 7828c, of the tubular member 7828 into a annular chamber 7834 defined between the internal annular recess 7808 of the expansion cone 7802 and the tubular member 7828. In an exemplary embodiment, a second fluidic material 7844 may be housed in the annular chamber 7834 below tubular piston 7842 and in an annular chamber 7836 defined between the external annular recess 7810 of the expansion cone 7802 and the expandable tubular member 7830. In an exemplary embodiment, the fluidic material 7844 includes one or more lubricant materials suitable for lubricating the interface between the expansion cone 7802 and the expandable tubular member 7830 during the radial expansion process. If the operating pressure of the fluidic material 7832 exceeds a predetermined value, which will vary as a function of the operating characteristics of the check valves, 7826a and 7826b, and tubular piston 7840, the tubular piston is displaced within annular chamber 7834, thereby pumping the second fluidic material through the longitudinal passages, 7812a and 7812b, into the annular chamber 7836. The pressurized fluidic material 7844 is then conveyed into the external grooves, 7824a, 7824b, and 7824c, through the longitudinal

passages, 7814a and 7814b, and the radial passages, 7816a, 7816b, 7816c, 7818a, 7818b, and 7818c, into the interface between the expansion cone 7802 and the expandable tubular member 7830. In an embodiment, magnetic coil 7854 may trigger a high-pressure impulse in volume of fluidic material in annular recess 7836 from a magnetic field created in magnetic coil 7854 and thereby increase the pressure in the fluidic material. The pressurized fluidic material 7844 is then conveyed into the external grooves, 7824a, 7824b, and 7824c, through the longitudinal passages, 7814a and 7814b, and the radial passages, 7816a, 7816b, 7816c, 7818a, 7818b, and 7818c, into the interface between the expansion cone 7802 and the expandable tubular member 7830.

[00428] In an exemplary embodiment, the rate of injection of the fluidic material 7844 into the external grooves, 7824a, 7824b, and 7824c, depends on the operating pressure of the fluidic material and the operating characteristics of the spring-biased check valves, 7826a and 7826b, and tubular piston 7840. In this manner, during the radial expansion process, the fluidic material 7844 may be controllably injected and metered into the interface between the tapered external expansion surface 7824 of the expansion cone 7802 and the expandable tubular member 7830 continuously during the radial expansion and plastic deformation of the tubular member. In an exemplary embodiment, the fluidic material 7844 may be injected into the external grooves, 7824a, 7824b, and 7824c only when required, or as desired. Thus, the trailing edge portion of the interface between the tapered external expansion surface 7824 of the expansion cone 7802 and the expandable tubular member 7830 may be provided with an increased supply of lubricant, thereby reducing the amount of force required to radially expand and plastically deform the expandable tubular member.

[00429] In an embodiment, valves 7826a and 7826b, permits lubricant flow when the input pressure of the fluidic material 7832 exceeds a predetermined pressure limit, which may be a factor of diameter of the tubular member, the length of the tubular member and the desired amount of lubricant to be dispensed. In an embodiment, tubular piston 7840 pumps the fluidic material 7844 into the annular chamber 7836, based on the input pressure of the fluidic material 7832, such as, for example, when the input pressure of the fluidic material 7844 exceeds a predetermined pressure limit, which may be a factor of diameter of the tubular member 7830, the length of the tubular member 7830 and the desired amount of lubricant to be injected.

[00430] In an exemplary embodiment, the second fluidic material 7844 in an annular chamber 7836 below tubular piston 7840 may be preloaded into expansion cone 7800 prior to being used to expand tubular member 7802. Alternatively, the lubricant may be replenished by a lubrication source located in a remote location from expansion cone 7800.

[00431] In an alternate embodiment, the tubular piston 7840 and spring-biased check valves, 7826a and 7826b, may be omitted, and/or used in combination with other types of

flow metering devices such as, for example, passive flow control devices, active flow control devices, fixed orifices, and/or variable orifices.

[00432] In an exemplary embodiment, magnetic coil 7854 triggers a high-pressure impulse in the lubricant in annular recess 7836 by means of a magnetic field created by in magnetic coil 7854 when current is generated by power source 7860 and run through magnetic coil 7854. In an exemplary embodiment, when current generated by power source 7860 is run through magnetic coil 7854 via cables 7856a and 7856b in the fluidic materials 7844 in annular chamber 7836, a magnetic field is generated around the magnetic coils 7854 that may trigger a high-pressure gaseous expansion within an enclosed volume of fluidic materials 7844 by means of force/impulse from a strong magnetic field. The expansion may create a pressure, allowing more lubricant to flow between the expansion cone 7800 and the tubular member 7830 and thereby reducing the friction and working pressure behind the expansion cone 7800. In an exemplary embodiment, cables, 7856a and 7856b may be used to provide power to the magnetic coils 7854 that may generate the magnetic field.

[00433] Referring to Fig. 70, an embodiment of a system 7900 for lubricating the interface between an expansion cone and a tubular member during the expansion process will now be described. As illustrated in Fig. 70, an expansion cone 7902 includes a body 7904 that defines a centrally positioned longitudinal passage 7906, an internal annular recess 7908, an external annular recess 7910, longitudinal passages, 7912a and 7912b, fluidicly coupled between the internal and external annular recesses, longitudinal passages, 7914a and 7914b, fluidicly coupled to the external annular recess, radial passages, 7916a, 7916b, and 7916c, fluidicly coupled to the longitudinal passage 7914a, radial passages, 7917a and 7917b, fluidicly coupled to the longitudinal passage 7906 and radial passage 7928c and 79 28d, and includes a front end face 7920, a rear end face 7922, and a tapered external expansion surface 7924 including spaced apart external grooves, 7924a, 7924b, and 7924c, that are fluidicly coupled to the radial passages, 7914a, 7916a, 7914b, 7916b, 7914c, and 7916c, respectively. Spring-biased check valves, 7926a and 7926b, are received within, mate with, and are operably coupled to, the longitudinal passages, 7914a and 7914b, respectively, for controlling the flow of fluidic materials therethrough. A tubular member 7928 that defines a longitudinal passage 7928a and radial passages, 7928b and 7928c, that are fluidicly coupled to the internal annular recess 7908 of the expansion cone 7902 is received within, mates with, and is coupled to the centrally positioned longitudinal passage 7906 of the expansion cone. A tubular piston 7940 defines a passageway 7940a that receives, mates with and is slidably coupled to the tubular member 7928 and is received within, mates with and is slidably coupled to internal annular recess 7932, of the expansion cone.

[00434] In an exemplary embodiment, during operation of the system 7900, the expansion cone 7902 is positioned within, and displaced relative to, an expandable tubular member 7930 thereby radially expanding and plastically deforming the expandable tubular member. In an exemplary embodiment, the expansion cone 7902 is displaced relative to the expandable tubular member 7930 by injecting a pressurized fluidic material 7932 into and through the passage 7928a of the tubular member 7928. As a result, the expansion cone 7902 is displaced in a direction 7933 relative to the expandable tubular member 7930. In an exemplary embodiment, the fluidic material 7932 includes one or more lubricant materials suitable for lubricating the interface between the expansion cone 7902 and the expandable tubular member 7930 during the radial expansion process. In particular, in an exemplary embodiment, the fluidic material 7932 is conveyed through the radial passages, 7928b and 7928c, of the tubular member 7928 into a annular chamber 7934 defined between the internal annular recess 7908 of the expansion cone 7902 and the tubular member 7928. In an exemplary embodiment, a second fluidic material 7944 may be housed in the annular chamber 7934 below tubular piston 7942 and in an annular chamber 7936 defined between the external annular recess 7910 of the expansion cone 7902 and the expandable tubular member 7930. In an exemplary embodiment, the fluidic material 7944 includes one or more lubricant materials suitable for lubricating the interface between the expansion cone 7902 and the expandable tubular member 7930 during the radial expansion process. If the operating pressure of the fluidic material 7932 exceeds a predetermined value, which will vary as a function of the operating characteristics of the check valves, 7926a and 7926b, and tubular piston 7940, the tubular piston is displaced within annular chamber 7937, thereby pumping the second fluidic material through the longitudinal passages, 7912a and 7912b, into the annular chamber 7936. The pressurized fluidic material 7944 is then conveyed into the external grooves, 7924a, 7924b, and 7924c, through the longitudinal passages, 7914a and 7914b, and the radial passages, 7916a, 7916b, 7916c, 7918a, 7918b, and 7918c, into the interface between the expansion cone 7902 and the expandable tubular member 7930. Similarly, in an exemplary embodiment, the fluidic material 7932 is conveyed through the radial passages, 7928d and 7928e, of the tubular member 7928 and through radial passages, 7917a and 7917b, into a passageway 7952 defined between the expansion cone 7902 and the tubular member 7930.

[00435] In an exemplary embodiment, the rate of injection of the fluidic material 7944 into the external grooves, 7924a, 7924b, and 7924c, depends on the operating pressure of the fluidic material and the operating characteristics of the spring-biased check valves, 7926a and 7926b, and tubular piston 7940. In this manner, during the radial expansion process, the fluidic material 7944 may be controllably injected and metered into the interface between the tapered external expansion surface 7924 of the expansion cone 7902 and the

expandable tubular member 7930 continuously during the radial expansion and plastic deformation of the tubular member. In an exemplary embodiment, the fluidic material 7944 may be injected into the external grooves, 7924a, 7924b, and 7924c only when required, or as desired. Thus, the trailing edge portion of the interface between the tapered external expansion surface 7924 of the expansion cone 7902 and the expandable tubular member 7930 may be provided with an increased supply of lubricant, thereby reducing the amount of force required to radially expand and plastically deform the expandable tubular member.

[00436] The rate of injection of fluidic material 7932 into passageway 7952 between expansion cone 7900 and tubular member 7902 depends on the input pressure of the fluidic material 7932. Since, the rate of injection of the second fluidic material 7944 into the external grooves, 7924a, 7924b, and 7924c, depends on the operating pressure of the fluidic material and the operating characteristics of the spring-biased check valves, 7926a and 7926b, and tubular piston 7940, the delivery of the fluidic material 7930 into passageway 7952 may be at a different pressure than the pressure of the fluidic material 7932 injected into passageway 7952 between expansion cone 7900 and tubular member 7902.

[00437] In an embodiment, valves 7926a and 7926b, permits lubricant flow when the input pressure of the fluidic material 7932 exceeds a predetermined pressure limit, which may be a factor of diameter of the tubular member, the length of the tubular member and the desired amount of lubricant to be dispensed. In an embodiment, tubular piston 7940 pumps the fluidic material 7944 into the annular chamber 7936, based on the input pressure of the fluidic material 7932, such as, for example, when the input pressure of the fluidic material 7944 exceeds a predetermined pressure limit, which may be a factor of diameter of the tubular member 7930, the length of the tubular member 7930 and the desired amount of lubricant to be injected.

[00438] In an exemplary embodiment, the second fluidic material 7944 in an annular chamber 7936 below tubular piston 7940 may be preloaded into expansion cone 7900 prior to being used to expand tubular member 7902. Alternatively, the lubricant may be replenished by a lubrication source located in a remote location from expansion cone 7900.

[00439] In an alternate embodiment, the tubular piston 7940 and spring-biased check valves, 7926a and 7926b, may be omitted, and/or used in combination with other types of flow metering devices such as, for example, passive flow control devices, active flow control devices, fixed orifices, and/or variable orifices.

[00440] It is understood that variations may be made in the foregoing expansion lubricant delivery systems without departing from the scope of the invention. For example, the teachings of the present illustrative embodiments may be used to vary the expansion cone size, shape, and external and internal structure. Furthermore, the elements and teachings of the various illustrative embodiments may be combined in whole or in part in

some or all of the illustrative embodiments. In addition, one or more of the elements and teachings of the various illustrative embodiments may be omitted, at least in part, and/or combined, at least in part, with one or more of the other elements and teachings of the various illustrative embodiments.

[00441] For example, In an exemplary embodiment, valve may not be used in the expansion cone. In another exemplary embodiment only one or a plurality of lubricant reservoirs may be utilized in the expansion cone.

Lubricants

[00442] When selecting a lubricant for a system for lubricating the interface between an expansion cone and a tubular member during the expansion process, the lubricant may be any media that may assist in reducing the friction between the expansion cone and a tubular member, including any fluidic material. Several factors may be considered, including the coefficient of friction between the expansion cone and tubular member, the size and complexity of the expansion cone, and the lubricant injection pressure, length of the tubular member and the amount of lubricant to be dispersed. The lubricant may include wet lubricants and/or solid lubricants. It is expected that the lubricant typically need to withstand at least 5000 psi of pressure.

[00443] In an exemplary embodiment, the lubricants for a system for lubricating the interface between an expansion cone and a tubular member during the expansion process may include, conventional commercial lubricants (natural and synthetic), working hydraulic fluid mud currently used in expandable tubular systems, and working hydraulic fluid mud blended with solid lubricants to improve lubricity. In an exemplary embodiment, a lithium based (non-synthetic) multipurpose grease combined with a solid lubricant may be used as the lubricant. In an exemplary embodiment, a grease lubricant for this application may be composed of a solid lubricant in a moderately high temperature resistant thickener. In an exemplary embodiment, the lubricant may have at least 10% Graphite or 10% Molybdenum Disulfide in a thickener with a dropping point above 350-400F. In an exemplary embodiment, two lubricants, which meet the requirements state above, and their respective suppliers, are as follows:

Lubricant Name	Manufacturer	Composition	Supplier
339-S Graphite Grease	Dixon Lube	30% Graphite	Dixon Lubricants and Specialty Products, Asbury, New Jersey
#3HT Moli-Grease	Bemol	15% Molybdenum	The Rose Mill Company, East Harford, Connecticut

[00444] Exemplary embodiments of lubricants that may be used in a system for lubricating the interface between an expansion cone and a tubular member may consist of the following component in the weight percentages indicated:

Component	Weight Percentage	Characteristic	Examples
1	64.25 – 90.89%	Base oil	A natural triglyceride oil which is, such as for example, fish, animal or vegetable triglyceride oil, or mixtures thereof. The triglyceride oil is a vegetable triglyceride oil, such as for example, sunflower seed oil, soybean oil, rapeseed oil canola oil, palm nut oil, palm oil, olive oil, rapeseed oil, canola oil, linseed oil, ground nut oil, soybean oil, cottonseed oil, sunflower seed oil, pumpkin seed oil, coconut oil, corn oil, castor oil, walnut oil and mixtures thereof. A natural or synthetic oil, which may be an ester wherein unsaturation as above triglycerides. The ester may be formed by a transesterification reaction of suitable monobasic and/or dibasic organic acids with primary, secondary or tertiary alcohols. An example of such a naturally occurring ester is jojoba oil and such a synthetic ester is lauryl oleate. The ester mentioned above may be formed by the reaction of unsaturated acids with polyhydric alcohols, such as for example, neopentyl glycol, trimethylolylethane, trimethylolpropane or pentaerythritol. Examples of such a reaction product are pentaerythritol monooleate, dioleate, trioleate, and the like. Example commercially available products are as follows: Canola oil from Cargil Inc(Agri-Pure 60, Agri-Pure -85) or Lambent (Oleocal 102); and Sunflower oil (Lubrizol 7631)
2	0.02 - 0.05%	Metal deactivator	Triazol and benzotriazol derivatives, such as for example, tolyltriazol.

Component	Weight Percentage	Characteristic	Examples
			Example commercially available products are as follows: Tolyltriazole, from PMC Inc (Cobratec TT-100); and 1H-Benzotriazole-1-Methanamine, N-N-bis(2-ethylhexyl)-methyl, from Ciba-Geigy Corp (Reomet 39)
3	0.5 – 3.0%	Antioxidants	Aromatic amine antioxidants and/or hindered phenolic antioxidants antioxidants, such as for example, 2,6-bis (tert butyl-4-methylphenol , BHT). Example commercially available products are as follows: Octylated, Butylated Diphenylamine Antioxidant from Ciba-Geigy Corp (Irganox L 57); 2,6-bis (1,1-dimethylethyl)-4-methyl-Phenol, from PMC, Inc (BHT); and Benzenepropanoic acid, 3,5-bis (1,1-demethylethyl)-4-hydroxy-, thiodi-2,1-ethanediyl ester, from Ciba-Geigy Corp (Irganox 1035);
4	4 – 12%	Sulfurized natural oils	Sulfurized vegetable or animal fatty oils, with sulfur content 9% – 21%, such as for example 13.5% – 17.5%. Example commercially available products are as follows: Sulfurized vegetable oils from Rhein Chemie Corporation (Additin RC-2515); and Sulfurized Lard Oil from Ferro Corporation (HSL).
5	4 – 12%	Phosphate ester	Phosphoric acid esters with ethoxylated fatty (C12– C15) alcohols, preferably mixture of phosphoric acid ester with ethoxylated lauryl alcohol and phosphoric acid ester with ethoxylated tridecyl alcohol. Example commercially available products are as follows: Phosphoric acid ester with ethoxylated lauryl alcohol and phosphoric acid ester with ethoxylated tridecyl alcohol from Houghton international (Houghton 5653).
6	0.4 – 1.5%	Phosphoric acid	Phosphoric acid. An example commercially available product is phosphoric acid from Rhodia.
7	0.08 – 1.5%	Viscosity modifier	Polyacrylates, polymethacrylates, vinylpyrrolidone/methacrylate-copolymers, polyvinylpyrrolidones, polybutanes, olefin-copolymers, styrene/-acrylate-copolymers, polyethers, such as for example, styrene or butadiene - styrene polymer. An example commercially available product is Styrene Hydrocarbon Polymer from Lubrizol Corporation (Lubrizol® 7440S).

Component	Weight Percentage	Characteristic	Examples
8	0.1 – 0.5%	Pour-point depressant	Polymethacrylates, alkylated naphthalene derivatives, such as for example, alkyl ester copolymers. An example commercially available product is Alkyl ester copolymer from Lubrizol Corporation (Lubrizol 6662)
9	0.01 – 0.2%	Defoamer	Silicon based antifoam agent. An example commercially available product is Silicon based antifoam agent from Ultra Additives (Foam Ban 103)
10	0 – 5%	Carboxylic acid soaps	Alkali, alkanolamine, alkyl amine or alkoxylated amine salts of mono- or dibasic fatty acids, or mixture thereof. An example commercially available product is Soap formed in situ as a product of reaction between Tall Oil Fatty Acids (Sylvatal ® D30LR from Arizona Chemical Co.) and triethanol amine (TEA 99 from Huntsman Corporation)

The lubricant may optionally contain various other additives, or mixture thereof, in order to improve the basic properties. In an exemplary embodiment, these further additives may include other antioxidants, metal deactivators, viscosity improvers, extreme–pressure additives, pour-point depressants, antifoam agents, dispersants, detergents, corrosion inhibitors, emulsifiers, demulsifiers and friction modifiers.

[00445] Exemplary experiments have shown that the lubricants identified in the table below, H1, H2, H3, H4, H5, H6, and H7, identified by the specified components in the weight percentages and the component manufactures and/or distributors indicated may perform in a system for lubricating the interface between an expansion cone and a tubular member:

Component		Manufacture/ Distributor	Example Lubricants						
			H1	H2	H3	H4	H5	H6	H7
1	Canola oil	Agri-Pure 60	77.81%	64.25%	90.89%	68.71%	82.07%	80.68%	80.31%
2	Tolyltriazole	Cobratec TT-100	0.04%	0.05%	0.02%	0.04%	0.03%	0.04%	0.04%
3	Aminic antioxidant Phenolic antioxidant	Irganox L 57 BHT	0 1.0%	1% 2%	0 0.5%	0.5% 1%	0.5% 0.5%	0 1%	0 1.1%
4	Sulfurized vegetable oil Or	Additin RC-2515 HSL	10%	12%	4%	12%			9%

Component		Manufacture/ Distributor	Example Lubricants						
			H1	H2	H3	H4	H5	H6	H7
	Sulfurized lard oil						10%	8%	
5	Phosphoric acid ester with ethoxylated lauryl alcohol and phosphoric acid ester with ethoxylated tridecyl alcohol	Rhodofac RS 410+ Rhodofac PC 100	9%	12%	4%	10%	5%	9%	8%
6	Phosphoric acid	Phosphoric acid	1%	1.5%	0.4%	1.1%	0.5%	1%	0.8%
7	Styrene Hydrocarbon Polymer	Lubrizol 7440S	0.8%	1.5%	0.08%	1.5%	0.1%	0.1%	0.4%
8	Alkyl ester copolymer	Lubrizol 6662	0.3%	0.5%	0.1%	0.1%	0.2%	0.1%	0.3%
9	Silicon based antifoam agent	Foam Ban 103	0.05%	0.2%	0.01%	0.05	0.1%	0.08%	0.05%
10	Carboxylic acid soap	Sylvatal ® D30LR + TEA 99	0	5%	0	5%	1%	0	0

[00446] In addition introducing lubricants between an expansion cone and a tubular member to reduce the coefficient of friction, the cone geometry, type of cone material, the cone texture (such as, for example, oil pocket on the surface of the cone) and coatings on the cone all affect the overall coefficient of friction between the expansion cone and the tubular member material, coating and finish.

Expansion Cone Material

[00447] When selecting the material for an expansion cone to reduce the coefficient of friction between an expansion cone and a tubular member in a system for lubricating the interface between an expansion cone and a tubular member during the expansion process, several factors may be considered, including, among other things, the coefficient of friction between the expansion cone and the tubular member, the size and complexity of the expansion cone, material hardness, compressive strength, wear resistance, corrosion resistance, toughness, surface finish ability and coatings. In an exemplary embodiment, example expansion cone materials include, high chrome, high carbon and molybdenum based tool steels, as well as a few powdered materials.

[00448] In several exemplary embodiments, the following commercially available expansion cone materials may be used in a system for lubricating the interface between an expansion cone and a tubular member: DC53, D2, D5, D7, M2, M4, CPM M4, 10V AND 3V. Referring to Figs. 71a, 71b, 71c, and 71d, the hardness, toughness, relative wear resistance and temper temperature characteristics are shown for each of the cone materials listed in the table above, respectively. Fig. 71e shows some hardness characteristics for some of the additional cone materials not listed above. Example expansion cone material manufactures and/or distributors are as follows:

1. International Mold Steel, Inc., of Florence, Kentucky distributes DC53 material; and
2. Crucible Materials Corporation of Syracuse, New York distributes D2, CPM M4, 10V AND 3V materials.

The characteristics of each material are specified below.

[00449] In an exemplary embodiment, an example of a DC53 material has the following characteristics:

Higher hardness (62-63 HRc) than D2 after heat treatment;
Twice the toughness of D2 with superior wear resistance;
20% higher fatigue strength than D2;
Smaller primary carbides than D2 protect the die from chipping and cracking;
Secondary refining process (DLF) reduces impurities;
Machines and grinds up to 40% faster than D2; and
Less residual stress after wire EDMing.

[00450] In an exemplary embodiment, an example of a DC53 material has the following Coefficient of Thermal Expansion (x10-6/C°):

	~100° C	~200°	~300°	~400°	~500°	~600°	~700°
DC53	12.2	12.0	12.3	12.8	13.2	13.4	13.0
Annealed							

[00451] In an exemplary embodiment, an example of a DC53 material has the following Coefficient of Thermal Conductivity (cal/cm·sec°C):

	Room Temp.	100°C	200°	300°	400°	500°	600°
DC53	0.057	0.060	0.064	0.064	0.065	0.062	
Quenched and Tempered							

[00452] In an exemplary embodiment, an example of a DC53 material has the following physical data:

Physical Characteristic	Data
Young's modulus (E)	21,700
Specific Gravity	7.87
Modulus of Rigidity (G)	8,480
Poisson's Ratio (v)	0.28

[00453] In an exemplary embodiment, an example of a DC53 material can be hardened to 62-63 HRc in the same manner as D2, and when tempered at high temperatures (520° to 530°C), it assumes excellent properties. Even when tempered at lower temperatures (180° to 200°C), its performance is equivalent to or better than that of D2. This improved hardenability makes heat treatment easier and reduces hardness problems due to vacuum heat treatment, which uses gas cooling.

[00454] In an exemplary embodiment, an example of a DC53 material displays superior wear-resistance to D2 when tempered at high temperatures (520°C) and equal wear resistance to D2 when tempered at low temperatures. High resistance to temper softening minimizes seizing and galling on the die surface. DC53 is ideal for dies needing to maintain high surface hardness against frictional heat between the die surface and the worked materials.

[00455] In an exemplary embodiment, an example of a D2 material is, AISI Type D2 Tool Steel that is air-quenched from 1010°C and tempered at 450°C, which falls into the following subcategories: cold work steel; high carbon steel; metal; and tool steel. The AISI Type D2 Tool Steel has the following properties:

Mechanical Properties Metric English Comments -

Hardness, Knoop 682 Converted from Rockwell C hardness;

Hardness, Rockwell C 58;

Hardness, Vickers 661;

Izod Impact, Unnotched 63 J 46.5 ft-lb; and

Thermal Properties -

CTE, linear 20°C 10.5 µm/m-°C 5.83 µin/in-°F 20 - 100°C;

CTE, linear 250°C 11.8 µm/m-°C 6.56 µin/in-°F from 0-300°C (68-570°F); and

CTE, linear 500°C 12.5 µm/m-°C 6.94 µin/in-°F from 0-500°C (68-930°F).

[00456] In an exemplary embodiment, the AISI Type D2 Tool Steel has the following

material composition:

Component	Wt. %
C	1.4 - 1.6
Co	Max 1
Cr	11 – 13
Mn	Max 0.6
Mo	0.7 - 1.2
P	Max 0.03
S	Max 0.03
Si	Max 0.6
V	Max 1.1

[00457] In an exemplary embodiment, an example of a D3 material is, AISI Type D3 Tool Steel that is oil-quenched from 980°C (1800°F) and tempered at 450°C, which falls into the following subcategories: cold work steel; high carbon steel; metal; and tool steel. The AISI Type D3 Tool Steel has the following properties:

Mechanical Properties Metric English Comments -

Hardness, Knoop 682 682 Converted from Rockwell C hardness;

Hardness, Rockwell C 58 58;

Hardness, Vickers 661 661;

Izod Impact, Unnotched 29 J 21.4 ft-lb; and

Thermal Properties -

CTE, linear 20°C 10.7 µm/m-°C 5.94 µin/in-°F 20 - 100°C;

CTE, linear 250°C 12.1 µm/m-°C 6.72 µin/in-°F from 0-300°C (68-570°F); and

CTE, linear 500°C 12.8 µm/m-°C 7.11 µin/in-°F from 0-500°C (68-930°F).

[00458] In an exemplary embodiment, the AISI Type D3 Tool Steel has the following material composition:

Component	Wt. %
C	2 - 2.35
Cr	11 – 13
Mn	Max 0.6
P	Max 0.03
S	Max 0.03
Si	Max 0.6
V	Max 1.1

Component	Wt. %
W	Max 1

[00459] In an exemplary embodiment, an example of a D5 material has the following characteristics:

Category	Characteristic
Principal Design Features	This alloy is one of the Cold Work, high Carbon/ Chromium type tool steels. It is capable of deep hardening with minimal distortion from air quenching after heat treatment. It has low resistance to heat softening and should not be used at elevated temperatures.
Applications	Applications include thread rolling, blanking or forming dies operating at temperatures below 900 F.
Machinability	Machinability of D5 is relatively poor. Using water hardening (W group) simple alloy tool steel as a base of 100% the D5 alloy would rate 40%.
Forming	Forming is by means of forging or machining
Welding	The alloy may be welded. Consult the alloy supplier for proper procedures.
Heat Treatment	Preheat very slowly up to 1500 F then increase temperature to 1850 F and hold at temperature for 20 to 45 minutes. Air cool (air quench).
Forging	Forge at 1950 F down to 1750 F. Do not forge below 1700 F.
Cold Working	Cold working with the alloy in the annealed condition may be accomplished by conventional methods.
Annealing	Anneal at 1625 F followed by slow cooling in the furnace at a rate of cooling of 40 F per hour or less.
Aging	Not applicable to this alloy.
Tempering	Temper between 400 F (Rockwell C 61) and 1000 F (Rockwell C 54).
Hardening	See "Heat Treatment" and "Tempering".

[00460] In an exemplary embodiment, an example of a D5 material has the following material composition:

Component	Wt. %
Carbon	1.4 - 1.6
Chromium	11 - 13
Cobalt	2.5 - 3.5
Iron	Balance
Manganese	0.6 max
Molybdenum	0.7 - 1.2
Phosphorus	0.03 max
Silicon	0.6 max
Sulfur	0.03 max
Vanadium	1 max

[00461] In an exemplary embodiment, an example of a D5 material has the following physical data:

Physical Characteristic	Data
Density (lb / cu. in.)	0.283
Specific Gravity	7.8
Melting Point (Deg F)	2600
Modulus of Elasticity Tension	29

[00462] In an exemplary embodiment, an example of a D7 material has the following characteristics:

Category	Characteristic
Principal Design Features	This alloy is one of the Cold Work, high Carbon/ Chromium type tool steels.
Corrosion Resistance	Corrosion resistance of this alloy is better than that of plain carbon steels. However it will rust unless given protective treatment. Applications include thread rolling, blanking or forming dies operating at temperatures below 900 F.

[00463] In an exemplary embodiment, an example of a D7 material has the following material composition:

Component	Wt. %
Carbon	2.15 - 2.5
Chromium	11.5 - 13.5
Iron	Balance
Manganese	0.6 max

Component	Wt. %
Molybdenum	0.7 - 1.2
Phosphorus	0.03 max
Silicon	0.6 max
Sulfur	0.03 max
Vanadium	3.8 - 4.4

[00464] In an exemplary embodiment, an example of a D7 material has the following physical data:

Physical Characteristic	Data
Density (lb / cu. in.)	0.283

[00465] In an exemplary embodiment, an example of a M2 material is, Allegheny Ludlum M2 Tool Steel, UNS T11302, which falls into the following subcategories: metal; tool steel. The Allegheny Ludlum M2 Tool Steel has the following material composition:

Component	Wt. %
C	0.84
Cr	4.15
Fe	83
Mo	4.65
V	1.85
W	5.65

[00466] In an exemplary embodiment, an example of a M4 has the following material composition:

Component	Wt. %
Carbon	1.25 - 1.4
Chromium	3.75 - 4.75
Iron	Balance
Manganese	0.15 - 0.4
Molybdenum	4.25 - 5.5
Phosphorus	0.03 max
Silicon	0.2 - 0.45
Sulfur	0.03 max

Component	Wt. %
Tungsten	5.25 - 6.5
Vanadium	3.75 - 4.5

[00467] In an exemplary embodiment, an example of a M4 material has the following characteristics:

Category	Characteristic
Principal Design Features	M4 is another in the Molybdenum High Speed Tool Steels. It has a relatively high 1.3% carbon content for high hardness and excellent wear resistance.
Applications	Used for cutting tools of all types for machining operations.
Machinability	Machinability is relatively low, rating 40% that of the water hardening (W group) tool steels which are relatively easy to machine.
Forming	Forming in the annealed condition is satisfactory by conventional methods.
Welding	This is an alloy steel and may be welded. Consult the supplier for details.
Heat Treatment	Preheat at 1450 F and then heat rapidly to 2225 F for 3 to 5 minutes followed by oil, salt bath or air quench.
Forging	Forge at 2050 F down to 1700 F. Do not attempt to continue forging below 1700 F.
Cold Working	Cold working may be accomplished by conventional methods with the alloy in the annealed condition.
Annealing	Anneal at 1625 F and slow furnace cool at 40 F per hour or less.
Aging	Not applicable to this alloy.
Tempering	Temper at 1050 F for a Rockwell C hardness of 62 to 66.
Hardening	See "Heat Treatment" and "Tempering".
Corrosion Resistance	Not normally employed in applications requiring corrosion resistance.
Hot Working	M4 may be hot forged. No data in regard to hot working . Consult the alloy supplier for temperatures.

Other Comments	M4 is one of the best of the Molybdenum High Speed Tool Steels in regard to wear resistance. However it has low toughness.

[00468] In an exemplary embodiment, an example of a M4 material has the following physical data:

Physical Characteristic	Data
Density (lb / cu. in.)	0.295
Specific Gravity	8.16
Melting Point (Deg F)	2600
Modulus of Elasticity Tension	29

[00469] In an exemplary embodiment, the characteristics of exemplary CPM M4, 10V and 3V materials may be found in the resources listed below.

Cone Materials	Manufacture/Distributor	Data Sheet (if available)
CPM M4	Crucible Materials Corporation, Syracuse, New York	DS351 12/01 CPM M4 Crucible Material Corp.
10V	Crucible Materials Corporation, Syracuse, New York	DS317 03/02 CPM 10V Crucible Material Corp.
3V	Crucible Materials Corporation, Syracuse, New York	DS406 03/02 CPM3V Crucible Material Corp.

Expansion Cone Coating and Polish

[00470] Several expansion cone finish techniques may be used to reduce the surface roughness of the an expansion cone, including for example applying coating, polishing the surface, chrome plating, cryogenics and REM® Isotropic Finishing (available from Taylor Race Engineering, Plano, Texas). When selecting a coating for an expansion cone in a system for lubricating the interface between an expansion cone and a tubular member during the expansion process, several factors may be considered, including the coefficient of friction between an expansion cone and a tubular member, cone material hardness, cone wear resistance, surface finish and the compatibility of the coating to the cone material.

[00471] In several exemplary experimental embodiments, the following coatings with specified characteristics may be utilized as a coating for an expansion cone in a tubular member during the expansion process:

	PVD	CVD	CVD for DLC's	Thermal Spray
Deposition Temperature	200-450 °C	500-1000 °C	200-450 °C	< 150 °C
Hardness	2000-4000 HV	2000-5000 HV	Up to 8000 HV	900-1700 HV
Adhesion (Bond)	Excellent	Excellent	Excellent	Good
Coating Thickness	3-5 microns	1-5 microns	1-3 microns	.003-.008 inch
Coatable Materials	Most metals	Many restrictions	Most metals	Most metals
Repairability	Most coatings, strip and recoat	Typically none, some coatings strippable	Typically none, some able to burn off	Most coatings, strip and recoat
Post Coating Processing	None	Possible Heat Treating	None	Grinding or Machining

[00472] In an exemplary embodiment, at least two thin film deposition processes may be used as coatings for an expansion cone in a tubular member during the expansion process; Chemical Vapor Deposition (CVD) and Physical Vapor Deposition (PVD). Both processes may yield hard coatings with high lubricity for forming and cutting. Each coating is very thin, such as, for example, in the order of microns, and the bond to the expansion cone substrate surface is a metallurgical bond. These two features of vapor deposition coatings are very conducive for high load and shear application. Thin film coatings are typically used with a cone material to support the coating. Referring to Fig. 71e, a comparison of the hardness of a few thin film coatings and cone materials is presented.

[00473] Many CVD coatings are processed at temperature above 500C, which may have an impact on the expansion cone material hardness. Re-hardening is available for the expansion cone material in the event that hardness is lost during the CVD coating process. However, for many metals, the dimensional tolerance of the component may change during the re-hardening process and may need to be accounted for. In an exemplary embodiment, a low process temperature Diamond Like Carbon (DLC) coating may be used as a coating for an expansion cone in a tubular member during the expansion process.

[00474] PVD coatings are well suited to function as a coating for an expansion cone in a tubular member during the expansion process. The PVD thin film coatings are typically processed at temperature below 400 C, which may not effect the hardness of the expansion cone material. PVD typically produce well bonded, high hardness coatings. In an exemplary embodiment, either a Titanium Nitride or Titanium Carbonitride coating may be used as a coating for an expansion cone in a tubular member during the expansion process.

[00475] The thermal spray coating process typically requires a soft expansion cone material for a high strength coating bond, which may be important during the tubular member expansion process due to the potential for high shear forces on the expansion cone. A high strength bond with an expansion cone may be obtained with a very high velocity thermal spray equipment. Post-coating work, such as for example, machining or grinding, may be utilized after the application of a thermal spray coating to an expansion cone to achieve the desired surface.

[00476] The REM® Isotropic Finishing process for an expansion cone involves two steps. The first step, the refinement process, involves a chemical interaction on the surface of the expansion cone. A soft, thin (one micron) film is formed on the surface of the expansion cone. The expansion cone interacts with the ceramic media in a special vibratory tub, this film is physically removed from the peaks of the processed part and the valleys are unaffected. The chemically induced film re-forms only at the peaks that are interacting with the vibratory media, and the process repeats itself. Over time, the peaks are removed, leaving only the valleys, producing the improved micro finish on the expansion cone. The second step is the burnish process. After the required micro finish is achieved, a mild alkaline mixture is introduced. After a relatively short period a polished, chrome-like finish is produced. In addition to the polishing effects, this step effectively removes all traces of the film formation on the expansion cone from the refinement process.

[00477] Referring to Fig. 72, an example method 7880 for radially expanding a tubular member is described. In an exemplary embodiment, the expansion cone and tubular member are placed in a wellbore, step 7880. Lubrication is introduced into the interface between the expansion cone and the tubular member, step 7884. Tubular member is radially expanded by the expansion cone using one or more conventional methods in step 7884, by, for example, displacing, translating, and/or rotating the expansion cone relative to the tubular member.

[00478] In an exemplary embodiment, one or more of the lubrication systems, expansion devices and elements of the expansion cones 5100, 5200, 5300, 5400, 5500, 5600, 5700, 5800, 5900, 6000, 6100, 6200, 6300, 6600, 6700, 6800, 6900, 7000 and 7100 are incorporated into the method 7880 for expanding tubular members described above with reference to Fig. 72. In an exemplary embodiment, one or more of the lubricant delivery systems 7200, 7300, 7400, 7500, 7600, 7700, 7800 and 7900 are incorporated into the method 7880 and apparatus for expanding tubular members described above with reference to Fig. 72. In an exemplary embodiment, one or more of the lubricants described above are incorporated into the method 7880 and apparatus for expanding tubular members described above with reference to Fig. 72. In an exemplary embodiment, one or more of the cone materials described above are incorporated into the method 7880 and apparatus for

expanding tubular members described above with reference to Fig. 72. In an exemplary embodiment, one or more of the cone finish techniques described above are incorporated into the method 7880 and apparatus for expanding tubular members described above with reference to Fig. 72.

[00479] In several exemplary embodiment, one or more of the lubrication systems and lubricants described above are incorporated into the methods and apparatus for expanding tubular members described above with reference to Figs. 1-30. In several exemplary embodiments, one or more of the lubrication systems, expansion devices and elements of the expansion cones 5100, 5200, 5300, 5400, 5500, 5600, 5700, 5800, 5900, 6000, 6100, 6200, 6300, 6600, 6700, 6800, 6900, 7000 and 7100 are incorporated into the methods and apparatus for expanding tubular members described above with reference to Figs. 1-99. In several exemplary embodiments, one or more of the lubricant delivery systems 7200, 7300, 7400, 7500, 7600, 7700, 7800 and 7900 are incorporated into the methods and apparatus for expanding tubular members described above with reference to Figs. 1-99. In several exemplary embodiments, one or more of the lubricants described above are incorporated into the methods and apparatus for expanding tubular members described above with reference to Figs. 1-99. In an exemplary embodiment, one or more of the cone materials described above are incorporated into the methods and apparatus for expanding tubular members described above with reference to Figs. 1-99. In an exemplary embodiment, one or more of the cone finish techniques described above are incorporated into the methods and apparatus for expanding tubular members described above with reference to Figs. 1-99.

[00480] In this manner, the amount of force required to radially expand a tubular member in the formation and/or repair of a wellbore casing, pipeline, or structural support is significantly reduced. Furthermore, the increased lubrication provided to the interface between an expansion cone and tubular member greatly reduces the amount of galling or seizure caused by the interface between the expansion cone and the tubular member during the radial expansion process thereby permitting larger continuous sections of tubulars to be radially expanded in a single continuous operation. Thus, use of the expansion cones 5100, 5200, 5300, 5400, 5500, 5600, 5700, 5800, 5900, 6000, 6100, 6200, 6300, 6600, 6700, 6800, 6900, 7000 and 7100 and/or lubricant delivery systems 7200, 7300, 7400, 7500, 7600, 7700, 7800 and 7900 and/or the lubricants described above reduces the operating pressures required for radial expansion and thereby reduces the sizes of the required hydraulic pumps and related equipment. In addition, failure, bursting, and/or buckling of tubular members during the radial expansion process is significantly reduced, and the success ratio of the radial expansion process is greatly increased.

[00481] In several exemplary embodiments, one or more of the lubrication systems, lubricants, lubricant delivery systems, expansion cone materials and cone finish techniques

described above may be incorporated into one or more of the following conventional expansion devices: a) an expansion cone; b) a rotary expansion device; c) a hydroforming expansion device; d) an impulsive force expansion device; e) any one of the expansion devices commercially available from, or disclosed in any of the published patent applications or issued patents, of Weatherford International, Baker Hughes, Halliburton Energy Services, Shell Oil Co., Schlumberger, and/or Enventure Global Technology L.L.C.

[00482] In several exemplary embodiments, a tubular members may be radially expanded and plastically deformed using one or more of the lubrication systems, lubricants, lubricant delivery systems, expansion cone materials and cone finish techniques described above in conjunction with other conventional methods for radially expanding and plastically deforming tubular members such as, for example, internal pressurization, hydroforming, and/or roller expansion devices and/or any one or combination of the conventional commercially available expansion products and services available from Baker Hughes, Weatherford International, and/or Enventure Global Technology L.L.C.

[00483] In several exemplary experimental embodiments, many of the lubricants specified above were tested with different types of expansion cones in tubular member in different conditions to determine the expansion forces necessary to expand the respective tubular members. For comparison purposes, tests were also performed on various different tubular members and cones without lubricants. The results of the tests relate to the effect of friction on a system for lubricating the interface between an expansion cone and a tubular member.

[00484] The following equation defines the effective force (F_{eff}) of a system for reducing the coefficient of friction in the interface between an expansion cone and a tubular member during the expansion process:

$$F_{eff}= k_{geo}(F/(2\sin\beta+\mu_{fric}); \qquad (25)$$

where:

F = Force on Tool (Input Pressure)

F_{eff} = Effective Force on the Cone Surface

k_{geo} = Coefficient of Geometry

μ_{fric} = Coefficient of Friction

β = Cone Angle.

The following equation defines the expansion force (F) on an expansion cone of a system radially expanding a tubular member using an expansion cone during the expansion process:

$$F= \pi Dt\ (1+f\cot\beta)\ Y\varepsilon \qquad (26)$$

where:

F – Expansion force;

D – Inside diameter of tubular member;

t – Wall thickness of tubular member'

f – Coefficient of friction between the tubular member and expansion cone;

Y- Yield strength the tubular material; and

ε – Expansion rate of the tubular material.

Fig. 73a illustrates the forces on expansion cone 8000 in tubular member 8002 during the expansion process. It is apparent from the equations listed directly above that the load on the expansion cone surface may be an important parameter in system and that the exemplary embodiments of structures of the surfaces of the systems; mechanisms for delivering lubricating fluid to the surfaces of the systems; lubricating fluids delivered to the system; different compositions of the system; and compositions of the tubular member described above have an impact on that load.

[00485] Fig. 73b illustrates example elements in a system for lubricating the interface between an expansion cone and a tubular member during the expansion process that may have an impact on the effective friction forces of the system. Such elements include, the surface 8102 of the tubular member 8100, the coating 8104 on the surface 8102 such as, for example, a low friction soft coating, the surface 8106 of the expansion cone 8108, the coating 8110 on the expansion cone 8108 such as, for example, a self-lubricating hard film, and the lubricant 8112 such as, for example, oil or grease and lubricated mud located between the tubular member 8100 and the expansion cone 8108. Regarding the surfaces of expansion cone 8108 and tubular member 8100, both the surface roughness, such as, for example, a rough or polished finish, and the texture, such as, for example, a pattern in the surface may play a role in contributing to the overall friction of the system.

[00486] Referring to Figs. 73c and 73d, illustrations of a smoother expansion cone finish and a rougher expansion cone finish, respectively, will now be described. For discussion purposes only, the term roughness refers to the roughness 8010 of the planar part of the surface. The term texture refers to the patter in the surface, such as, for example, the holes 8012 in the surface. The holes may represent oil pockets will capture oil that in turn acts as a liquid ball bearing and thus may increase the lubricity of the surface of the expansion cone. A range of roughness for an expansion cone that may decrease the coefficient of friction between an expansion cone and a tubular member during radial expansion and plastic deformation is 0.02 – 0.1 micrometers.

[00487] In an exemplary embodiment, a calculation was completed to determine the effective force F_{eff} on a cone surface and the energy equations necessary to calculate frictional effects for tribological elements, that is the elements that have an impact on coefficient of friction between an expansion cone and a tubular member during the expansion process. The system was modeled for static and dynamic conditions. The tool

velocity in the system allowed for static kinematic calculations with static and dynamic coefficients of friction. A preliminary evaluation shows that up to 25% of input pressure may be required to compensate for dynamic frictional effects and that the effective force on the cone could exceed 5000 psi during tubular member expansion.

[00488] During the expansion process, a tubular member may withstand a finite amount of expansion pressure from an expansion cone, the maximum acceptable expansion pressure, beyond which tubular member failure may occur, including fracturing and splitting. Laboratory tests have shown that the maximum acceptable expansion pressure for an 5 ½" LSX-80 tubular member having a 0.3" wall thickness is approximately 5000psi. Referring to Fig. 74, a chart illustrates a curve depicting the pressure (y-axis) versus coefficient of friction (x-axis) for an 5 ½" LSX-80 tubular member having a 0.3" wall thickness. The maximum coefficient of friction corresponding to the maximum acceptable pressure for the 5 ½" LSX-80 tubular member having a 0.3" wall thickness is approximately 0.2. Referring to Figs. 75 and 76, charts illustrate information similar to that shown in Fig. 74 on a logarithmic scale; one showing pressure in terms of pounds per square inch and the other showing pressure in terms of pounds. As illustrated in Figs. 74, 75 and 76, as the coefficient of friction increases, the expansion pressure increases.

[00489] Referring to Fig. 77, a chart depicting the results in an exemplary experimental embodiment that shows the expansion forces in pounds per square inch over time applied to a 6" LSX80 tubular member coated with a Gear Kote coating, which is a graphite based coating distributed by Commercial Coating Services International, Ltd. The expansion process began with no lubricant between the expansion cone and the tubular member, period 8900. A steady increase in expansion force was observed. After the introduction of oil between the expansion cone and the tubular member at point 8902, the expansion force decreased significantly over the period 8904 suggesting that expansion force is related to the coefficient of friction between the expansion cone and the tubular member. Expansion forces increased over time during the expansion process in the period 8904 after the introduction of oil, but did so at a much slower rate than under the dry friction conditions in period 8900. Once a lubricant, such as, for example oil, is introduce during the expansion process, the system coefficient of friction is reduced and thus the expansion forces decreases.

[00490] In several exemplary embodiments, many of the lubricants specified above were tested with different types of expansion cones in tubular members in different conditions to determine the expansion forces necessary to expand the respective tubular members. For comparison purposes, tests were also performed on various different tubular members and cones with out lubricants. The results of the test are shown in Fig. 78 - Fig. 98.

[00491] Referring to Fig. 78, a chart depicting the results of experimental test that show the coefficient of friction for several different combinations of expansion systems using a 1 5/8" Low Carbon Steel expansion cone made of D2 material is shown. The following samples are represented on the chart:

	Expansion System Components					
Sample	**Tubular member**	**Tubular Member Internal Coating**	**Expansion Cone External Surface Coating**	**Lubricant**	**Expansion Cone Finish**	**Coefficient of Friction**
1	Heavy corroded	None	None	None	None	0.36 - 0.40
2	Clean tubular member	None	None	None	None	0.16 – 0.22
3	Clean tubular member	None	None	Oleon	None	0.14 – 0.16
4	Clean tubular member	Graphite based coating	None	None	None	0.12 –0.15
5	Clean tubular member	None	None	H1	None	0.09 – 0.14
6	Clean tubular member	EGT MS-9075	None	None	None	0.08 – 0.10
7	Clean tubular member	EGT MS-9075	None	H1	None	0.04 – 0.05
8	Clean tubular member	EGT MS-9075	DC53 cone material + Phygen film	H1	REM	0.02 – 0.03

The lowest coefficient of friction, approximately 0.02, resulted from Sample 8. Sample 7 also produce a low coefficient of friction in the order of approximately 0,05

EGT MS – 9075 is a Teflon based coating (polytetrafluoroethylene or PTFE), distributed by Enventure Global Technology, L.L.C., Houston Texas, is shown. Phygen film is a chrome nitride coating and is distributed by Phygen, Inc., Minneapolis, Minnesota.

[00492] Referring to Fig. 79a, a three dimensional photograph having a 5X magnification and a field of the view 1.20 X 0.90 mm of the surface of an expansion cone made of D2 material is shown. The expansion cone made of D2 material, has the following surface characteristics:

Surface Characteristic	**Value**
Ra:	277.930 nm
Rz:	3.13 um
Rpk:	377.167 nm
Rk:	829.31 nm
Rvk:	216.287 nm
Sty X Pc:	3.88 /mm
Sty Y Pc:	6.13 /mm
NormVolume:	0.822 BCM

[00493] The surface characteristics listed in the table above are well known. Some of the characteristics listed in the table above have the following meanings:

a. Ra is the roughness average, is the arithmetic average of the absolute values of the surface height deviations measured from the best fitting plane, cylinder or sphere;

b. Rz is the average maximum height of the surface;

c. Rpk – is the reduced peak height, a measure of the peak height above the nominal/core roughness;

d. Rvk is the reduced valley depth, which is a measure of the valley depth below the nominal /core roughness; and

e. Rk is the core roughness depth which is a measure of the nominal or “core” roughness (peak-to-valley) of the surface with the predominant peaks and valleys removed.

[00494] Referring to Fig. 79b, a three dimensional photograph having a 5X magnification and a field of the view 1.20 X 0.90 mm of the surface of an expansion cone made of DC53 material having a Phygen film and REM polish is shown. The expansion cone made of DC53 material, has the following surface characteristics:

Surface Characteristic	Value
Ra:	60.205 nm
Rz:	1.99 um
Rpk:	25.009 nm
Rk:	152.12 nm
Rvk:	92.963 nm
Sty X Pc:	2.21 /mm
Sty Y Pc:	3.53 /mm
NormVolume:	0.047 BCM

[00495] Referring to Figs. 80a and 80b, photo micrographs of the expansion cone made of D2 material shown in Fig. 79a and the expansion cone made of DC53 material shown in Fig. 79b are shown, respectively.

[00496] Referring to Figs. 81a and 81b, an x-profile of the an expansion cone made of D2 material shown in Fig. 79a and the expansion cone made of DC53 shown in Fig. 81b are shown, respectively. Note in Fig. 81b that a hole pocket 9000 in surface the expansion cone made of DC53 exists, which may create an oil pocket. Hole pockets may be desirable and may enhance the reduction of the effect of friction on the expansion system. Hole pockets may collect oil, act as a liquid ball bearings when in contact with a tubular member and may increase the lubricity of the system by introducing more lubricant in the interface between the expansion cone and the tubular member.

[00497] Referring to Figs. 82a and 82b, the bearing ratio for the expansion cone made of D2 shown in Fig. 79a and the expansion cone made of DC53 shown in Fig. 79b are shown, respectively. The bearing ratio represents the length of material surface (expressed as a percentage of the evaluation length L) at a depth below the highest peak.

[00498] Referring to Fig. 83a, a three dimensional photograph having a 50X magnification and a field of the view 1.20 X 0.90 mm of the surface of an expansion cone made of D2 material is shown. The expansion cone made of D2 material, has the following surface characteristics:

Surface Characteristic	**Value**
Ra:	275.671 nm
Rz:	2.34 um
Rpk:	262.729 nm
Rk:	872.91 nm
Rvk:	270.620 nm
Sty X Pc:	22.83 /mm
Sty Y Pc:	38.65 /mm
NormVolume:	0.469 BCM

[00499] Referring to Fig. 83b, three dimensional photographs having a 50X magnification and a field of the view 1.20 X 0.90 mm of the surface of an expansion cone made of DC53 material having a Phygen film and REM polish is shown. The expansion cone made of DC53 material, has the following surface characteristics:

Surface Characteristic	**Value**
Ra:	55.085 nm
Rz:	678.35 nm
Rpk:	32.764 nm
Rk:	163.53 nm
Rvk:	82.624 nm
Sty X Pc:	48.84 /mm
Sty Y Pc:	61.73 /mm
NormVolume:	0.075 BCM

[00500] Referring to Figs. 84a and 84b, photo micrographs of the expansion cone made of D2 material shown in Fig. 83a and the expansion cone made of DC53 material shown in Fig. 83b are shown, respectively.

[00501] Referring to Figs. 85a and 85b, an x-profile of the expansion cone made of D2 material shown in Fig. 83a and the expansion cone made of DC53 material shown in Fig. 83b are shown, respectively.

[00502] Referring to Figs. 86a and 86b, the bearing ratio for the expansion cone made of D2 material shown in Fig. 83a and the expansion cone made of DC53 material shown in Fig. 83b, respectively, are shown.

[00503] Referring to Fig. 87, a chart depicting the results of experimental tests that show the expansion forces in terms of load for several different combinations of expansion systems, which range from a system using only a cone to a system with a cone, combined with one or more of the friction reduction mechanisms, such as for example, a tubular member coating, a cone coating, a lubricant between the expansion cone and the tubular member, and a cone finish, in a corroded tubular member exposed to seawater for 24 hours is shown. Several of the tribological elements identified in Fig. 39a analyzed during the tests. The following samples are represented on the chart:

	Expansion System Components					
Sample	**Cone Material**	**Tubular Member Internal Coating**	**Expansion Cone External Surface Coating**	**Lubricant**	**Expansion Cone Finish**	**Approximate Load Range (Lbs)**
1	DC53	None	Phygen film	None	REM	22000 - 23500
2	D2	None	None	None	None	22300 - 22900
3	DC53	None	Phygen film	H1	REM	17000 – 17200
4	D2	None	None	H1	None	20500 - 20900
5	DC53	None	Phygen film	H6	REM	15800 – 16000
6	D2	None	None	H6	None	16900 – 17100
7	D2	Gear Kote	None	None	None	15800 – 17500
8	D2	Gear Kote	None	Sea Water	None	13800 - 15500

[00504] Referring to Fig. 88, a chart depicting the results of experimental tests that show the expansion forces in terms of load for several different combinations of expansion

systems in a tubular member coated with EGT MS – 9075, distributed by Enventure Global Technology, L.L.C., Houston Texas, is shown. The following samples are represented on the chart:

	Expansion System Components					
Sample	**Expansion Cone**	**Tubular Member Internal Coating**	**Expansion Cone External Surface Coating**	**Lubricant**	**Expansion Cone Finish**	**Approximate Load Range (Lbs)**
1	DC53	EGT MS –9075	Phygen film	None	REM	22000 - 23500
2	D2	EGT MS –9075	None	None	None	22300 - 22900
3	DC53	EGT MS –9075	Phygen film	H1	REM	12900 – 13200
4	D2	EGT MS –9075	None	H1	None	12000 – 12300
5	DC53	EGT MS –9075	Phygen film	H6	REM	12800 – 12900
6	D2	EGT MS –9075	None	H6	None	13500 – 13800
7	D2	Gear Kote	None	None	None	15800 – 17500
8	D2	Gear Kote	None	Sea Water	None	13800 - 15500

[00505] Referring to Fig. 89, a chart depicting the results of experimental tests that show the expansion forces in terms of load for several different combinations of expansion systems in a tubular member coated with a Brighton White Teflon-based coating with sea water is shown. The following samples are represented on the chart:

	Expansion System Components					
Sample	Cone	Tubular Member Internal Coating	Expansion Cone External Surface Coating	Lubricant	Expansion Cone Finish	Approximate Load Range (Lbs)
1	DC53	Brighton White Teflon-based	Phygen film	None	REM	22000 - 23500
2	D2	Brighton White Teflon-based	None	None	None	22300 - 22900
3	DC53	Brighton White Teflon-based	Phygen film	H1	REM	11500 – 12000
4	D2	Brighton White Teflon-based	None	H1	None	13200 – 14000
5	DC53	Brighton White Teflon-based	Phygen film	H6	REM	12800 - 13100
6	D2	Brighton White Teflon-based	None	H6	None	12200 - 12500
7	D2	Gear Kote	None	None	None	15800 – 17500
8	D2	Gear Kote	None	Sea Water	None	13800 - 15500

[00506] Referring to Fig. 90, a chart depicting the results of experimental tests that show the expansion forces in terms of load for several different combinations of expansion systems in a tubular member coated with Brighton Grey Acrilic-based coating is shown. The following samples are represented on the chart:

	Expansion System Components					
Sample	**Cone**	**Tubular Member Internal Coating**	**Expansion Cone External Surface Coating**	**Lubricant**	**Expansion Cone Finish**	**Approximate Load Range (Lbs)**
1	DC53	Brighton Grey Acrilic-based	Phygen film	None	REM	22000 - 23500
2	D2	Brighton White Teflon	None	None	None	22300 - 22900
3	DC53	Brighton Grey Acrilic-based	Phygen film	H1	REM	13000 – 13200
4	D2	Brighton Grey Acrilic-based	None	H1	None	14000 – 14400
5	DC53	Brighton Grey Acrilic-based	Phygen film	H6	REM	12700 – 12900
6	D2	Brighton Grey Acrilic-based	None	H6	None	14300 - 14800
7	D2	Gear Kote	None	None	None	15800 – 17500
8	D2	Gear Kote	None	Sea Water	None	13800 - 15500

[00507] Referring to Fig. 91, a chart depicting the results of experimental tests that show the expansion forces in terms of load for several different combinations of expansion systems in a tubular member is shown. The following samples are represented on the chart:

	Expansion System Components					
Sample	**Cone**	**Tubular Member Internal Coating**	**Expansion Cone External Surface Coating**	**Lubricant**	**Expansion Cone Finish**	**Approximate Load Range (Lbs)**
1	DC53		Phygen film	None	REM	17800 - 18200
2	DC53		Phygen film	H1	REM	14400 - 14900
3	DC53		Phygen film	H7	REM	16400 - 17200

[00508] Referring to Fig. 92, a chart depicting the results of experimental tests that show the expansion forces in terms of load for several different combinations of expansion systems in a tubular member is shown. The following samples are represented on the chart:

	Expansion System Components					
Sample	**Cone**	**Tubular Member Internal Coating**	**Expansion Cone External Surface Coating**	**Lubricant**	**Expansion Cone Finish**	**Approximate Load Range (Lbs)**
1	DC53	None	Phygen film	None	REM	15000 -17700
2	DC53	None	Phygen film	Oleon	REM	16400 - 17400
3	DC53	None	Phygen film	H1	REM	16300 – 16800
4	DC53	None	Phygen film	H2	REM	15800 – 16800
5	DC53	None	Phygen film	H3	REM	14500 – 16800
6	DC53	None	Phygen film	H4	REM	15300 – 17200
7	DC53	None	Phygen film	H5	REM	14100 – 16900
8	DC53	None	Phygen film	H6	REM	14600 - 15800

[00509] Referring to Fig. 93, a chart depicting the results of experimental tests that show the expansion forces in terms of load for several different combinations of expansion systems in a tubular member is shown. The following samples are represented on the chart:

	Expansion System Components					
Sample	**Cone**	**Tubular Member Internal Coating**	**Expansion Cone External Surface Coating**	**Lubricant**	**Expansion Cone Finish**	**Approximate Load Range (Lbs)**
1	None	None	None	None	None	0
2	D2	Gear Kote	None	None	None	15500 – 17600
3	DC53	None	Phygen film	Oleon	REM	16800 – 17100
4	DC53	None	Phygen film	H1	REM	16300 – 16800
5	DC53	None	Phygen film	H2	REM	15700 – 16200
6	DC53	None	Phygen film	H3	REM	14500 – 15400
7	DC53	None	Phygen film	H4	REM	17700 – 18100
8	DC53	None	Phygen film	H5	REM	14100 – 14500
9	DC53	None	Phygen film	H6	REM	14600 – 14800
10						16400 – 16600
11	DC53	None	Phygen film	Belesta	REM	14800 - 15200

[00510] Referring to Fig. 94, a chart depicting the results of experimental tests that show the expansion forces in terms of load for several different combinations of expansion systems in a tubular member is shown. The following samples are represented on the chart:

	Expansion System Components					
Sample	**Cone**	**Tubular Member Internal Coating**	**Expansion Cone External Surface Coating**	**Lubricant**	**Expansion Cone Finish**	**Approximate Load Range (Lbs)**
1	D2	Gear Kote	None	None	REM	15500 – 17700
2	D2	Gear Kote	None	Oleon	REM	16400 – 17400
3	D2	Gear Kote	None	H1	REM	16300 – 16800
4	D2	Gear Kote	None	H2	REM	15800 – 16800

	Expansion System Components					
Sample	**Cone**	**Tubular Member Internal Coating**	**Expansion Cone External Surface Coating**	**Lubricant**	**Expansion Cone Finish**	**Approximate Load Range (Lbs)**
5	D2	Gear Kote	None	H4	REM	14500 – 16800
6	D2	Gear Kote	None	H5	REM	15300 – 17200
7	D2	Gear Kote	None	H6	REM	14100 – 16900
8	D2	Gear Kote	None	H7	REM	14600 - 15400

[00511] Referring to Fig. 95, a chart depicting the results of experimental tests that show the expansion forces in terms of load for several different combinations of expansion systems in a tubular member is shown. The following samples are represented on the chart:

	Expansion System Components					
Sample	**Cone**	**Tubular Member Internal Coating**	**Expansion Cone External Surface Coating**	**Lubricant**	**Expansion Cone Finish**	**Approximate Load Range (Lbs)**
1	DC53	None	Phygen film	None	REM	19200 – 23000
2	DC53	None	Phygen film	None	REM	13800 – 15500
3	DC53	None	Phygen film	Oleon	REM	17800 - 18400
4	DC53	None	Phygen film	H1	REM	14300 – 14500
5	DC53	None	Phygen film	H3	REM	15000 – 15500
6	DC53	None	Phygen film	H5	REM	15800 – 16100
7	DC53	None	Phygen film	H6	REM	15600 - 15900

[00512] Referring to Fig. 96, a chart depicting the results of experimental tests that show the expansion forces in terms of load for several different combinations of expansion systems in a LSX80 tubular member is shown. The following samples are represented on the chart:

	Expansion System Components					
Sample	**Cone**	**Tubular Member Internal Coating**	**Expansion Cone External Surface Coating**	**Lubricant**	**Expansion Cone Finish**	**Approximate Load Range (Lbs)**
1	D2	None	None	Oleon	None	19700 – 20100
2	D2	None	None	H1	None	1600 – 16300
3	D2	None	None	H2	None	16800 – 17400
4	D2	None	None	H3	None	17200 – 17900
5	D2	None	None	H4	None	15500 – 15700
6	D2	None	None	H5	None	17700 – 18000
7	D2	None	None	H6	None	14700 – 15200
8	D2	None	None	H7	None	15800 – 16000
9	D2	None	None	HPL	None	18500 – 18800

[00513] Referring to Fig. 97, a chart depicting the results of experimental tests that show the expansion forces in terms of load for several different combinations of expansion systems in a LSX80 tubular member is shown. The following samples are represented on the chart:

	Expansion System Components					
Sample	**Cone**	**Tubular Member Internal Coating**	**Expansion Cone External Surface Coating**	**Lubricant**	**Expansion Cone Finish**	**Approximate Load Range (Lbs)**
1	D2	Gear Kote	None	None	None	16000 – 16200
2	D2	Gear Kote	None	Oleon	None	1500 – 15600
3	D2	Gear Kote	None	H1	None	12500 – 12700
4	D2	Gear Kote	None	H2	None	14500 – 14700
5	D2	Gear Kote	None	H3	None	13900 – 14100
6	D2	Gear Kote	None	H4	None	12500 – 12800
7	D2	Gear Kote	None	H5	None	14100 – 14500
8	D2	Gear Kote	None	H6	None	11600 - 12200

	Expansion System Components					
Sample	**Cone**	**Tubular Member Internal Coating**	**Expansion Cone External Surface Coating**	**Lubricant**	**Expansion Cone Finish**	**Approximate Load Range (Lbs)**
9	D2	Gear Kote	None	H7	None	12400 –12700

[00514] Referring to Fig. 98, a chart depicting the results of experimental tests that show the expansion forces in terms of load for several different combinations of expansion systems in a LSX80 tubular member is shown. The following samples are represented on the chart:

	Expansion System Components					
Sample	**Cone**	**Tubular Member Internal Coating**	**Expansion Cone External Surface Coating**	**Lubricant**	**Expansion Cone Finish**	**Approximate Load Range (Lbs)**
1	D2	Gear Kote	None	None	None	13400 - 13700
2	D2	Gear Kote	None	Oleon	None	12700 - 13000
3	D2	Gear Kote	None	H1	None	11700 – 12100
4	D2	Gear Kote	None	H3	None	12700 - 12900
5	D2	Gear Kote	None	H5	None	11500 - 12200

[00515] Referring to Fig. 99a, another exemplary embodiment of a system for lubricating the interface between an expansion cone and a tubular member during the expansion process will now be described. As illustrated in Fig. 99a, an expansion cone 10000, having a front end 10000a and a rear end 10000b, includes a tapered portion 10005 having an outer surface 10010, a spiral circumferential grooves 10015, and radial ports 10016. Referring to Fig. 99b, a photo micrograph of the outer surface 10010 of expansion cone 10000 of Fig. 99a is shown.

[00516] Referring to Fig. 99c, an embodiment of a system 10100 for lubricating the

interface between an expansion cone and a tubular member during the expansion process will now be described. As illustrated in Fig. 99c, an expansion cone 10102 includes a body 10104 that defines a centrally positioned longitudinal passage 10106, longitudinal passage 10112, radial passage 10116a, fluidicly coupled to the longitudinal passage 10112, radial passages, fluidicly coupled to the longitudinal passage 10106, and includes a front end face 10120, a rear end face 10122, and a tapered external expansion surface 10124 including spaced apart external grooves, 10124a, 10124b, and 10124c, that are fluidicly coupled to the radial passages, fluidicly coupled to the longitudinal passage 10106 through radial ports, respectively. A tubular member 10128 that defines a longitudinal passage 10128a and is received within, mates with, and is coupled to the centrally positioned longitudinal passage 10106 of the expansion cone. A tubular member 10128 that defines a longitudinal passage 10128a and is received within, mates with, and is coupled to the centrally positioned longitudinal passage 10112 of the expansion cone.

[00517] In an exemplary embodiment, during operation of the system 10100, the expansion cone 10102 is positioned within, and displaced relative to, an expandable tubular member thereby radially expanding and plastically deforming the expandable tubular member. In an exemplary embodiment, the expansion cone 10102 is displaced relative to the expandable tubular member by injecting a pressurized fluidic material 10132 into and through the passage 10128a of the tubular member 10128. As a result, the expansion cone 10102 is displaced in a direction 10133 relative to the expandable tubular member. In an exemplary embodiment, the fluidic material 10132 includes one or more lubricant materials suitable for lubricating the interface between the expansion cone 10102 and the expandable tubular member during the radial expansion process. In an exemplary embodiment, a second pressurized fluidic material 10144 is injected into and through the passage 10129a of the tubular member 10129 though pump 10130. In an exemplary embodiment, the fluidic material 10144 includes one or more lubricant materials suitable for lubricating the interface between the expansion cone 10102 and the expandable tubular member during the radial expansion process. The pressurized fluidic material 10132 may be then conveyed into the external grooves, 10124a, 10124b, and 10124c, into an interface between the expansion cone 10102 and the expandable tubular member. Similarly, in an exemplary embodiment, the fluidic material 10132 is conveyed through the radial passage 10129a, of the tubular member 10129 and through radial passage, 10116, into a passageway between the expansion cone 10102 and the tubular member.

[00518] In an exemplary embodiment, the rate of injection of the fluidic material 10144 into the external grooves, 10124a, 10124b, and 10124c, depends on the selected operating pressure of the fluidic material. In this manner, during the radial expansion process, the fluidic material 10144 may be controllably injected and metered into the interface between

the tapered external expansion surface 10124 of the expansion cone 10102 and the expandable tubular member 10130 continuously during the radial expansion and plastic deformation of the tubular member. In an exemplary embodiment, the fluidic material 10144 may be injected into the external grooves, 10124a, 10124b, and 10124c only when required, or as desired. Thus, the trailing edge portion of the interface between the tapered external expansion surface 10124 of the expansion cone 10102 and the expandable tubular member 10130 may be provided with an increased supply of lubricant, thereby reducing the amount of force required to radially expand and plastically deform the expandable tubular member.

[00519] The rate of injection of fluidic material 10132 into passageway 10152 between expansion cone 10100 and tubular member also depends the selected operating pressure of the fluidic material. Since, both the pressures for both fluidic materials, 10132 and 10144, are individually controlled, the pressures may be set at different operating pressures. In this manner, different areas of the interface between the expansion cone 10100 and a tubular member, during the radial expansion and plastic deformation of the tubular member using the expansion cone, can be provided with different formulations of lubricant materials and different operating pressures thereby permitting the control of friction within the interface to be precisely controlled.

[00520] One of the problems of the pipe material selection for expandable tubular application is an apparent contradiction or inconsistency between strength and elongation. To increase burst and collapse strength, material with higher yield strength is used. The higher yield strength generally corresponds to a decrease in the fracture toughness and correspondingly limits the extent of achievable expansion.

[00521] It is desirable to select the steel material for the tubing by balancing steel strength with amount absorbed energy measure by Charpy testing. Generally these tests are done on samples cut from tubular members. It has been found to be beneficial to cut directional samples both longitudinally oriented (aligned with the axis) and circumferentially oriented (generally perpendicular to the axis). This method of selecting samples is beneficial when both directional orientations are used yet does not completely evaluate possible and characteristic anisotropy throughout a tubular member. Moreover, for small diameter tubing samples representative of the circumferential direction may be difficult and sometimes impossible to obtain because of the significant curvature of the tubing.

[00522] To further facilitate evaluation of a tubular member for suitability for expansion it has been found beneficial according to one aspect of the invention to consider the plastic strain ratio. One such ratio is called a Lankford value (or r-value) which is the ratio of the strains occurring in the width and thickness directions measured in a single tension test. The plastic strain ratio (r or Lankford - value) with a value of greater than 1.0 is found to be more resistant to thinning and better suited to tubular expansion. Such a Lankford value is

found to be a measure of plastic anisotropy. The Lankford value (r) may be calculated by the Equation 2 below:

$$r = \frac{\ln \frac{b_o}{b_k}}{\ln \frac{L_k b_k}{l_o b_o}} \qquad \text{Equation 2}$$

where,

r - normal anisotropy coefficient

b_o & b_k - initial and final width

L_o & L_k - initial and final length

[00523] However, it is time consuming and labor intensive for this parameter to be measured using samples cut from real parts such as from the tubular members. The tubular members will have anisotropic characteristics due to crystallographic or "grain " orientation and mechanically induced differences such as impurities, inclusions, and voids, requiring multiple samples for reliably complete information. Moreover, with individual samples, only local characteristics are determined and the complete anisotropy of the tubular member may not be determinable. Further some of the tubular members have small diameters so that cutting samples oriented in a circumferential direction is not always possible. Information regarding the characteristics in the circumferential direction has been found to be important because the plastic deformation during expansion of the tubular members occurs to a very large extent in the circumferential direction,

[00524] One aspect of the present exemplary embodiments comprises the development of an improved solution for anisotropy evaluation, including a kind of plastic strain ratio similar to the Lankford parameter that is measured using real tubular members subjected to axial loading.

[00525] Fig. 100 depicts in a schematic fragmentary cross-sectional view along a plane along and through the axis 1002 of a tubular member 1000 that is tested with axial opposed forces 1004 and 1005. The tubular member 1000 is axially stretched beyond the elastic limit, through yielding and to ultimate yield or fracture. Measurements of the force and the OD and ID during the process produce test data that can be used in the formula below to produce an expandability coefficient *"f "* as set forth in Equation 1 above. Alternatively a coefficient called a formability anisotropy coefficient *F(r)* that is function of the normal anisotropy Lankford coefficient *r* may be determined as in Equation 3 below:

$$F(r) = \frac{\ln \frac{b_o}{b_k}}{\ln \frac{L_k b_k}{l_o b_o}} \qquad \text{Equation 3}$$

F(r) - formability anisotropy coefficient

b_o & b_k - initial and final tube area ($inch^2$)

L_o & L_k - initial and final tube length (inch)

$b = (D^2\text{-}d^2)/4$- cross section tube area.

[00526] In either circumstance, *f* or *F(r),* the use of this testing method for an entire tubular member provides useful information including anisotropic characteristics or anisotropy of the tubular member for selecting or producing beneficial tubular members for down hole expansion, similar to the use of the Lankford value for a sheet material.

[00527] Just as values for stress and strain may be plotted for solid specimen samples, as schematically depicted in Fig 101, the values for conducting a test on the tubular member may also be plotted, as depicted in Fig 102. On this basis the expansion coefficient *f* (or the formability coefficient *F(r))* may be determined. It will be the best to measure distribution (Tensile-elongation) in longitudinal and circumferential directions simultaneously.

[00528] The foregoing expandability coefficient (or formability coefficient) is found to be useful in predicting good expansion results and may be further useful when used in combination with one or more other properties of a tubular member selected from stress-strain properties in one or more directional orientations of the material, strength & elongation, Charpy V-notch impact value in one or more directional orientations of the material, stress burst rupture, stress collapse rupture, yield strength, ductility, toughness, and strain-hardening exponent (n - value), and hardness.

[00529] In an exemplary embodiment, a tribological system is used to reduce friction and thereby minimize the expansion forces required during the radial expansion and plastic deformation of the tubular members that includes one or more of the following: (1) a tubular tribology system; (2) a drilling mud tribology system; (3) a lubrication tribology system; and (4) an expansion device tribology system.

[00530] In an exemplary embodiment, the tubular tribology system includes the application of coatings of lubricant to the interior surface of the tubular members.

[00531] In an exemplary embodiment, the drilling mud tribology system includes the addition of lubricating additives to the drilling mud.

[00532] In an exemplary embodiment, the lubrication tribology system includes the use of lubricating greases, self-lubricating expansion devices, automated injection/delivery of

lubricating greases into the interface between an expansion device and the tubular members, surfaces within the interface between the expansion device and the expandable tubular member that are self-lubricating, surfaces within the interface between the expansion device and the expandable tubular member that are textured, self-lubricating surfaces within the interface between the expansion device and the expandable tubular member that include diamond and/or ceramic inserts, thermosprayed coatings, fluoropolymer coatings, PVD films, and/or CVD films.

[00533] In an exemplary embodiment, the tubular members include one or more of the following characteristics: high burst and collapse, the ability to be radially expanded more than about 40%, high fracture toughness, defect tolerance, strain recovery @ 150 F, good bending fatigue, optimal residual stresses, and corrosion resistance to H_2S in order to provide optimal characteristics during and after radial expansion and plastic deformation.

[00534] In an exemplary embodiment, the tubular members are fabricated from a steel alloy having a charpy energy of at least about 90 ft-lbs in order to provided enhanced characteristics during and after radial expansion and plastic deformation of the expandable tubular member.

[00535] In an exemplary embodiment, the tubular members are fabricated from a steel alloy having a weight percentage of carbon of less than about 0.08% in order to provide enhanced characteristics during and after radial expansion and plastic deformation of the tubular members.

[00536] In an exemplary embodiment, the tubular members are fabricated from a steel alloy having reduced sulfur content in order to minimize hydrogen induced cracking.

[00537] In an exemplary embodiment, the tubular members are fabricated from a steel alloy having a weight percentage of carbon of less than about 0.20 % and a charpy-V-notch impact toughness of at least about 6 joules in order to provide enhanced characteristics during and after radial expansion and plastic deformation of the tubular members.

[00538] In an exemplary embodiment, the tubular members are fabricated from a steel alloy having a low weight percentage of carbon in order to enhance toughness, ductility, weldability, shelf energy, and hydrogen induced cracking resistance.

[00539] In several exemplary embodiments, the tubular members are fabricated from a steel alloy having the following percentage compositions in order to provide enhanced characteristics during and after radial expansion and plastic deformation of the tubular members:

	C	Si	Mn	P	S	Al	N	Cu	Cr	Ni	Nb	Ti	Co	Mo
EXAMPLE A	0.030	0.22	1.74	0.005	0.0005	0.028	0.0037	0.30	0.26	0.15	0.095	0.014	0.0034	
EXAMPLE B MIN	0.020	0.23	1.70	0.004	0.0005	0.026	0.0030	0.27	0.26	0.16	0.096	0.012	0.0021	
EXAMPLE B MAX	0.032	0.26	1.92	0.009	0.0010	0.035	0.0047	0.32	0.29	0.18	0.120	0.016	0.0050	
EXAMPLE C	0.028	0.24	1.77	0.007	0.0008	0.030	0.0035	0.29	0.27	0.17	0.101	0.014	0.0028	0.0020
EXAMPLE D	0.08	0.30	0.5	0.07	0.005		0.010	0.10	0.50	0.10				
EXAMPLE E	0.0028	0.009	0.17	0.011	0.006	0.027	0.0029		0.029	0.014	0.035	0.007		
EXAMPLE F	0.03	0.1	0.1	0.015	0.005					18.0		0.6	9	5
EXAMPLE G	0.002	0.01	0.15	0.07	0.005	0.04	0.0025				0.015	0.010		

[00540] In an exemplary embodiment, the ratio of the outside diameter D of the tubular members to the wall thickness t of the tubular members range from about 12 to 22 in order to enhance the collapse strength of the radially expanded and plastically deformed tubular members.

[00541] In an exemplary embodiment, the outer portion of the wall thickness of the radially expanded and plastically deformed tubular members includes tensile residual stresses in order to enhance the collapse strength following radial expansion and plastic deformation.

[00542] In several exemplary experimental embodiments, reducing residual stresses in samples of the tubular members prior to radial expansion and plastic deformation increased the collapse strength of the radially expanded and plastically deformed tubular members.

[00543] In several exemplary experimental embodiments, the collapse strength of radially expanded and plastically deformed samples of the tubulars were determined on an as-received basis, after strain aging at 250 F for 5 hours to reduce residual stresses, and after strain aging at 350 F for 14 days to reduce residual stresses as follows:

<u>Tubular Sample</u>	<u>Collapse Strength After 10% Radial Expansion</u>
Tubular Sample 1 – as received from manufacturer	4000 psi
Tubular Sample 1 – strain aged at 250 F for 5 hours to reduce residual stresses	4800 psi
Tubular Sample 1 – strain aged at 350 F for 14 days to reduce residual stresses	5000 psi

[00544] As indicated by the above table, reducing residual stresses in the tubular members, prior to radial expansion and plastic deformation, significantly increased the resulting collapse strength – post expansion.

[00545] In several exemplary experimental embodiments, the collapse strength of radially expanded and plastically deformed samples of the tubulars were determined on an as-received basis, after strain aging at 250 F for 5 hours to reduce residual stresses, and after strain aging at 350 F for 14 days to reduce residual stresses as follows:

Tubular Sample	Collapse Strength After 20% Radial Expansion
Tubular Sample 1 – as received from manufacturer	3000 psi
Tubular Sample 1 – strain aged at 250 F for 5 hours to reduce residual stresses	4000 psi
Tubular Sample 1 – strain aged at 350 F for 14 days to reduce residual stresses	4250 psi

[00546] As indicated by the above table, reducing residual stresses in the tubular members, prior to radial expansion and plastic deformation, significantly increased the resulting collapse strength – post expansion.

[00547] In an exemplary experimental embodiment, residual stresses within a tubular member were decreased from about –12,000 psi to about –6,000 psi, a reduction of about 105%. As a result, the collapse strength of the resulting tubular member was increased from about 1550 psi to about 1750 psi. This was an unexpected result.

[00548] In several exemplary experimental embodiments, tubular members were radially expanded and plastically deformed using different lubricants to achieve a range of coefficients of friction between the tubular members and a solid expansion cone during the radial expansion and plastic deformation of the tubular members. As a result, the following experimental results were obtained:

SAMPLE	COEFFICIENT OF FRICTION	EXPANSION FORCE (lbf)	WALL THICKNESS (t)	RATIO OF DIAMETER TO WALL THICKNESS AFTER EXPANSION (D/t)	COLLAPSE STRENGTH (ksi)
1	0.125	145,900	0.305	24.8	2,379
2	0.075	143,000	0.350	21.6	3,243
3	0.02	149,900	0.450	16.8	5,837
4	0.02	125,800	0.500	15.1	5,359
5	0.02	125,800	0.500	15.1	8,443

The above tabular experimental results were unexpected. In particular, the resulting collapse strength of the radially expanded and plastically deformed tubular was increased by one or more of the following: 1) reducing the coefficient of friction; and/or 2) reducing the ratio of D/t.

[00549] Referring to Fig. 103, in an exemplary experimental embodiment, a sample of steel pipe, for which the normal manufacturing process was modified to include quenching and tempering (the "Quenched and Tempered Steel Pipe No. 1"), was tested to generate a stress vs. strain curve 10300. As illustrated in Fig. 103, the yield point of the curve 10300 was 76.8 ksi. Further stress and strain testing of the Quenched and Tempered Steel Pipe No. 1, yielded the following characteristics:

Sample	Yield Strength ksi	Yield/Tensile Strength Ratio	Elongation Longitudinal % PRIOR TO FAILURE	Width Reduction % PRIOR TO FAILURE	Wall Thickness Reduction % PRIOR TO FAILURE	Anisotropy
Quenched and Tempered Steel Pipe No. 1	76.8	0.82	16%	32%	45%	0.65

The testing results for the Quenched and Tempered Steel Pipe No. 1, illustrated in Fig. 103, and summarized above in tabular form were unexpected results. Thus, the modification of the normal manufacturing process of the Quenched and Tempered Steel Pipe No. 1, to include a quenching and tempering step, significantly and unexpectedly, enhanced the performance characteristics of the pipe thereby making the pipe particularly suited to use as an expandable tubular.

[00550] Referring to Fig. 104, in an exemplary experimental embodiment, a sample of 9 5/8" steel pipe, for which the normal manufacturing process was modified to include quenching and tempering (the "Quenched and Tempered Steel Pipe No. 2"), a sample of conventional 9 5/8" NT80-HE steel pipe from Nippon Steel, and a sample of conventional 9 5/8" NT55-HE steel pipe from Nippon Steel were tested to generate stress vs. strain curves 10400, 10402, and 10404, for the Quenched and Tempered Steel Pipe No. 2, the 9 5/8" NT80-HE steel pipe from Nippon Steel, and the 9 5/8" NT55-HE steel pipe from Nippon

Steel, respectively. As illustrated in Fig. 104, the yield points of the curves 10400, 10402, and 10404, were 84.4 ksi, 61.5 ksi, and 73.7 ksi, respectively. Further stress and strain testing of the Quenched and Tempered Steel Pipe No. 2, the 9 5/8" NT80-HE steel pipe from Nippon Steel, and the 9 5/8" NT55-HE steel pipe from Nippon Steel, yielded the following characteristics:

Sample	Yield Strength ksi	Yield/Tensile Strength Ratio	Elongation Longitudinal % PRIOR TO FAILURE	Width Reduction % PRIOR TO FAILURE	Wall Thickness Reduction % PRIOR TO FAILURE	Anisotropy
Quenched and Tempered Steel Pipe No. 2	84.4	0.840	20.5%	40.0%	41.8%	0.935
NT80-HE	61.5	0.62	16.5%	25.5%	47%	0.46
NT55-HE	73.7	0.67	13.5%	20.4%	37.5%	0.48

The testing results for the Quenched and Tempered Steel Pipe No. 2, illustrated in Fig. 104, and summarized above in tabular form were unexpected results. Thus, the modification of the normal manufacturing process of the Quenched and Tempered Steel Pipe No. 2, to include a quenching and tempering step, significantly and unexpectedly, enhanced the performance characteristics of the pipe, relative to the conventional NT80-HE and NT55-HE pipes, thereby making the pipe particularly suited to use as an expandable tubular.

[00551] In an exemplary experimental embodiment, samples of steel pipe, for which the normal manufacturing process was modified to include quenching and tempering (the "Quenched and Tempered Steel Pipe Nos. 3 and 4"), were stress and strain tested and exhibited the following characteristics:

Characteristic	Value	
	Quenched and Tempered Steel Pipe No. 3	Quenched and Tempered Steel Pipe No. 4
YIELD STRENGTH	81.25 ksi	78.77 ksi

Characteristic	Value	
	Quenched and Tempered Steel Pipe No. 3	Quenched and Tempered Steel Pipe No. 4
Y/T RATIO	0.829	0.822
ELONGATION PRIOR TO FAILURE	14.88%	15.90%
WIDTH REDUCTION PRIOR TO FAILURE	37.8%	44.0%
WALL THICKNESS REDUCTION PRIOR TO FAILURE	43.25%	43.33%
ANISOTROPY	0.830	1.03

The tabular experimental results presented above were unexpected.

[00552] In an exemplary experimental embodiment, samples of steel pipe, for which the normal manufacturing process was modified to include quenching and tempering (the "Quenched and Tempered Steel Pipe No. 5"), were stress and strain tested and exhibited the following characteristics:

Characteristic	Value
YIELD STRENGTH	80.19 ksi
Y/T RATIO	0.826
ELONGATION PRIOR TO FAILURE	15.25%
WIDTH REDUCTION PRIOR TO FAILURE	40.4%
WALL THICKNESS REDUCTION PRIOR TO FAILURE	43.3%
ANISOTROPY	0.915

The tabular experimental results presented above were unexpected.

[00553] In an exemplary experimental embodiment, a sample of steel pipe, for which the normal manufacturing process was modified to include quenching and tempering (the

"Quenched and Tempered Steel Pipe Nos. 6 and 7"), a sample of conventional NT80-HE steel pipe from Nippon Steel, and a sample of conventional NT55-HE steel pipe from Nippon Steel were tested to determine absorbed energy and flare expansion characteristics and exhibited the following characteristics:

Characteristic	Value			
	Quenched and Tempered Steel Pipe No. 6	Quenched and Tempered Steel Pipe No. 7	NT80-HE	NT55-HE
ABSORBED ENERGY - LONGITUDINAL	125 ft-lbs	145 ft-lbs	100 ft-lbs	50 ft-lbs
ABSORBED ENERGY - TRANSVERSE	59 ft-lbs	59 ft-lbs	40 ft-lbs	30 ft-lbs
ABSORBED ENERGY - WELD	176 ft-lbs	174 ft-lbs	70 ft-lbs	4 ft-lbs
FLARE EXPANSION	42%	52%	32%	30%

The testing results for the Quenched and Tempered Steel Pipe Nos. 6 and 7 summarized above in tabular form were unexpected results. Thus, the modification of the normal manufacturing process of the Quenched and Tempered Steel Pipe Nos. 6 and 7, to include a quenching and tempering step, significantly and unexpectedly, enhanced the performance characteristics of the pipe, relative to the conventional NT80-HE and NT55-HE pipes, thereby making the Quenched and Tempered Pipes particularly suited to use as an expandable tubular.

[00554] In an exemplary embodiment, the flare expansion of the Quenched and Tempered Steel Pipe Nos. 6 and 7, the sample of conventional NT80-HE steel pipe from Nippon Steel, and the sample of conventional NT55-HE steel pipe from Nippon Steel were performed by pressing a tapered solid expansion cone into an end of the pipe samples to radially expand and plastically deform the ends of the pipe samples.

[00555] In an exemplary experimental embodiment, samples of steel pipe, for which the normal manufacturing process was modified to include quenching and tempering (the "Quenched and Tempered Steel Pipe No. 8"), were stress and strain tested and exhibited the following characteristics:

Characteristic	Value
YIELD STRENGTH	88.8 ksi
Y/T RATIO	0.86
ELONGATION PRIOR TO FAILURE	22%
WIDTH REDUCTION PRIOR TO FAILURE	39%
WALL THICKNESS REDUCTION PRIOR TO FAILURE	41%
ANISOTROPY	0.93

The tabular experimental results presented above were unexpected.

[00556] In an exemplary experimental embodiment, a sample of steel pipe, for which the normal manufacturing process was modified to include quenching and tempering (the "Quenched and Tempered Steel Pipe No. 9"), a sample of conventional NT80-HE steel pipe from Nippon Steel, and a sample of conventional NT55-HE steel pipe from Nippon Steel were tested to determine absorbed energy and flare expansion characteristics and exhibited the following characteristics:

Characteristic	Value		
	Quenched and Tempered Steel Pipe No. 9	NT80-HE	NT55-HE
YIELD STRENGTH	84.4 ksi	73.7 ksi	61.5 ksi
YIELD/TENSILE STRENGTH RATIO	0.840	0.67	0.62
ELONGATION BEFORE FAILURE	20.5%	13.5%	16.5%
WIDTH REDUCTION BEFORE FAILURE	40.0%	20.4%	25.5%
WALL THICKNESS REDUCTION BEFORE FAILURE	41.8%	37.5%	47%
ANISOTROPY	0.935	0.48	0.46

The testing results for the Quenched and Tempered Steel Pipe No. 9 summarized above in tabular form were unexpected results. Thus, the modification of the normal manufacturing process of the Quenched and Tempered Steel Pipe No. 9, to include a quenching and tempering step, significantly and unexpectedly, enhanced the performance characteristics of the pipe, relative to the conventional NT80-HE and NT55-HE pipes, thereby making the Quenched and Tempered Pipes particularly suited to use as an expandable tubular.

[00557] In an exemplary experimental embodiment, samples of steel pipe, for which the normal manufacturing process was modified to include quenching and tempering (the "Quenched and Tempered Steel Pipe No. 10"), were stress and strain tested and exhibited the following characteristics:

Characteristic	Value
YIELD STRENGTH	84.6 ksi
Y/T RATIO	0.85
ELONGATION PRIOR TO FAILURE	21%
WIDTH REDUCTION PRIOR TO FAILURE	39%
WALL THICKNESS REDUCTION PRIOR TO FAILURE	43%
ANISOTROPY	0.88

The tabular experimental results presented above were unexpected.

[00558] In an exemplary embodiment, the composition of the Quench and Temper Steel Pipe Nos. 1 to 10 included the following weight percentages:

C	Si	Mn	P	S	Cu	Cr	Ni
0.27	0.14	1.28	0.009	0.005		0.14	

In an exemplary embodiment, the quenching of the Quench and Temper Steel Pipe Nos. 1 to 10 was provided at 970 C, and the tempering of the Quench and Temper Steel Pipe Nos. 1 to 10 was provided for 10 minutes at 670 C.

[00559] In an exemplary embodiment, using a combination of empirical, theoretical, and experimental data, electrical resistance pipe ("ERW") tubular members most suitable for radial expansion and plastic deformation exhibit the following characteristics:

Characteristic	Value
ABSORBED ENERGY IN THE LONGITUDINAL DIRECTION	at least 80 ft-lb
ABSORBED ENERGY IN THE TRANSVERSE DIRECTION	at least 60 ft-lb
ABSORBED ENERGY IN THE TRANSVERSE WELD AREA	at least 60 ft-lb
FLARE EXPANSION	45% to 75% MINIMUM W/O CRACKS
TENSILE STRENGTH	60 TO 120 ksi
YIELD STRENGTH	40 TO 100 ksi
Y/T RATIO	40% to 85% MAXIMUM
LONGITUDINAL ELONGATION PRIOR TO FAILURE	A MINIMUM OF 22% to 35%
WIDTH REDUCTION PRIOR TO FAILURE	A MINIMUM OF 30% to 45%
WALL THICKNESS REDUCTION PRIOR TO FAILURE	A MINIMUM OF 30% to 45%
ANISOTROPY	A MINIMUM OF 0.8 to 1.5

[00560] In an exemplary experimental embodiment, based upon theoretical, empirical, and experimental data, tubular members that exhibit the following characteristics are best suited for radial expansion and plastic deformation:

Characteristic	Value
YIELD STRENGTH	50 to 95 ksi
Y/T RATIO	less than 0.5 to 0.82
ELONGATION PRIOR TO FAILURE	greater than 16 to 30 %
WIDTH REDUCTION PRIOR TO FAILURE	greater than 32 to 45%
WALL THICKNESS REDUCTION PRIOR TO FAILURE	greater than 30 to 45%
ANISOTROPY	greater than 0.65 to 1.5

[00561] In an exemplary embodiment, as illustrated in Figs. 105 and 106, in an exemplary embodiment, a method 10500 of processing tubular members is implemented in which, in step 10502, a manufactured tubular member 10502a is received. In step 10504, the manufactured tubular member 10502a is then cold rolled to provide a cold-rolled tubular

member 10504a. In step 10506, the cold-rolled tubular member 10504a is then inter critical annealed to provide an annealed tubular member 10506a. In step 10508, the annealed tubular member 10506a is then positioned within a wellbore and radially expanded and plastically deformed in a conventional manner to provide a radially expanded and plastically deformed tubular member 10508a. In step 10510, the radially expanded and plastically deformed tubular member 10508a is then baked within the wellbore, using the ambient temperatures within the wellbore, to provide an after-baked tubular member 10510a. As illustrated in Fig. 106, the ultimate and final yield strength of the after-baked tubular member 10510a is greater than the yield strength of the manufactured tubular member 10502a. In an exemplary embodiment, the manufactured tubular member 10502a is a dual phase steel pipe or a Transformation Induced Plasticity ("TRIP") steel pipe.

[00562] In an exemplary embodiment, the dual phase steel manufactured pipe 10502a includes a microstructure having about 15% to 30% martensite and ferrite. In an exemplary embodiment, the dual phase steel manufactured pipe 10502a includes a composition of 0.1% C, 1.2% Mn, and 0.3% Si.

[00563] In an exemplary embodiment, as illustrated in Fig. 107, when the manufactured pipe 10502a is a dual phase steel, the initial microstructure of the pipe includes ferrite and pearlite. In an exemplary embodiment, in step 10506, the intercritical annealing of the cold rolled pipe 10504a is performed at about 750 C. As a result of the intercritical annealing, at least some of the pearlite is converted to austentite. Following the completion of the intercritical annealing in step 10506, the annealed pipe 10506a is allowed to cool. As a result of the cooling, at least some of the austentite in the annealed pipe 10506a is converted to martensite. In an exemplary embodiment, in step 10510, the baking of the radially expanded and plastically deformed pipe 10508a is provided within the wellbore at temperatures ranging from about 100 C to 250 C. In an exemplary embodiment, as a result of the baking step 10510, the radially expanded and plastically deformed pipe 10508a is stress-relieved and bake hardened.

[00564] In an exemplary embodiment, in step 10504 of the method 10500, as illustrated in Fig. 108, the temperature of the manufactured steel pipe 10502a follows a curve 10802 in which the steel pipe is deformed throughout the cooling progression of the curve at a plurality of separate stages, 10802a and 10802b. In an exemplary embodiment, during the first pipe rolling stage 10802a, insoluble precipitates within the pipe 10502a retard austentite growth and the deformation also promotes precipitation. In an exemplary embodiment, during the second pipe rolling state 10802b, insoluble precipitates within the pipe 10502a inhibit recrystallization and austentite grains are conditioned. As a result, the ultimate yield and collapse strength of the baked pipe 10510a is enhanced.

[00565] In several exemplary embodiments, the teachings of the present disclosure are combined with one or more of the teachings disclosed in FR 2 841 626, filed on 6/28/2002, and published on 1/2/2004, the disclosure of which is incorporated herein by reference.

[00566] A method of forming a tubular liner within a preexisting structure is provided that includes positioning a tubular assembly within the preexisting structure; and radially expanding and plastically deforming the tubular assembly within the preexisting structure, wherein, prior to the radial expansion and plastic deformation of the tubular assembly, a predetermined portion of the tubular assembly has a lower yield point than another portion of the tubular assembly. In an exemplary embodiment, the predetermined portion of the tubular assembly has a higher ductility and a lower yield point prior to the radial expansion and plastic deformation than after the radial expansion and plastic deformation. In an exemplary embodiment, the predetermined portion of the tubular assembly has a higher ductility prior to the radial expansion and plastic deformation than after the radial expansion and plastic deformation. In an exemplary embodiment, the predetermined portion of the tubular assembly has a lower yield point prior to the radial expansion and plastic deformation than after the radial expansion and plastic deformation. In an exemplary embodiment, the predetermined portion of the tubular assembly has a larger inside diameter after the radial expansion and plastic deformation than other portions of the tubular assembly. In an exemplary embodiment, the method further includes positioning another tubular assembly within the preexisting structure in overlapping relation to the tubular assembly; and radially expanding and plastically deforming the other tubular assembly within the preexisting structure, wherein, prior to the radial expansion and plastic deformation of the tubular assembly, a predetermined portion of the other tubular assembly has a lower yield point than another portion of the other tubular assembly. In an exemplary embodiment, the inside diameter of the radially expanded and plastically deformed other portion of the tubular assembly is equal to the inside diameter of the radially expanded and plastically deformed other portion of the other tubular assembly. In an exemplary embodiment, the predetermined portion of the tubular assembly includes an end portion of the tubular assembly. In an exemplary embodiment, the predetermined portion of the tubular assembly includes a plurality of predetermined portions of the tubular assembly. In an exemplary embodiment, the predetermined portion of the tubular assembly includes a plurality of spaced apart predetermined portions of the tubular assembly. In an exemplary embodiment, the other portion of the tubular assembly includes an end portion of the tubular assembly. In an exemplary embodiment, the other portion of the tubular assembly includes a plurality of other portions of the tubular assembly. In an exemplary embodiment, the other portion of the tubular assembly includes a plurality of spaced apart other portions of the tubular

assembly. In an exemplary embodiment, the tubular assembly includes a plurality of tubular members coupled to one another by corresponding tubular couplings. In an exemplary embodiment, the tubular couplings include the predetermined portions of the tubular assembly; and wherein the tubular members comprise the other portion of the tubular assembly. In an exemplary embodiment, one or more of the tubular couplings include the predetermined portions of the tubular assembly. In an exemplary embodiment, one or more of the tubular members include the predetermined portions of the tubular assembly. In an exemplary embodiment, the predetermined portion of the tubular assembly defines one or more openings. In an exemplary embodiment, one or more of the openings include slots. In an exemplary embodiment, the anisotropy for the predetermined portion of the tubular assembly is greater than 1. In an exemplary embodiment, the anisotropy for the predetermined portion of the tubular assembly is greater than 1. In an exemplary embodiment, the strain hardening exponent for the predetermined portion of the tubular assembly is greater than 0.12. In an exemplary embodiment, the anisotropy for the predetermined portion of the tubular assembly is greater than 1; and the strain hardening exponent for the predetermined portion of the tubular assembly is greater than 0.12. In an exemplary embodiment, the predetermined portion of the tubular assembly is a first steel alloy including: 0.065 % C, 1.44 % Mn, 0.01 % P, 0.002 % S, 0.24 % Si, 0.01 % Cu, 0.01 % Ni, and 0.02 % Cr. In an exemplary embodiment, the yield point of the predetermined portion of the tubular assembly is at most about 46.9 ksi prior to the radial expansion and plastic deformation; and the yield point of the predetermined portion of the tubular assembly is at least about 65.9 ksi after the radial expansion and plastic deformation. In an exemplary embodiment, the yield point of the predetermined portion of the tubular assembly after the radial expansion and plastic deformation is at least about 40 % greater than the yield point of the predetermined portion of the tubular assembly prior to the radial expansion and plastic deformation. In an exemplary embodiment, the anisotropy of the predetermined portion of the tubular assembly, prior to the radial expansion and plastic deformation, is about 1.48. In an exemplary embodiment, the predetermined portion of the tubular assembly includes a second steel alloy including: 0.18 % C, 1.28 % Mn, 0.017 % P, 0.004 % S, 0.29 % Si, 0.01 % Cu, 0.01 % Ni, and 0.03 % Cr. In an exemplary embodiment, the yield point of the predetermined portion of the tubular assembly is at most about 57.8 ksi prior to the radial expansion and plastic deformation; and the yield point of the predetermined portion of the tubular assembly is at least about 74.4 ksi after the radial expansion and plastic deformation. In an exemplary embodiment, the yield point of the predetermined portion of the tubular assembly after the radial expansion and plastic deformation is at least about 28 % greater than the yield point of the predetermined portion of the tubular assembly prior to the radial expansion and plastic deformation. In an exemplary embodiment, the anisotropy of the

predetermined portion of the tubular assembly, prior to the radial expansion and plastic deformation, is about 1.04. In an exemplary embodiment, the predetermined portion of the tubular assembly includes a third steel alloy including: 0.08 % C, 0.82 % Mn, 0.006 % P, 0.003 % S, 0.30 % Si, 0.16 % Cu, 0.05 % Ni, and 0.05 % Cr. In an exemplary embodiment, the anisotropy of the predetermined portion of the tubular assembly, prior to the radial expansion and plastic deformation, is about 1.92. In an exemplary embodiment, the predetermined portion of the tubular assembly includes a fourth steel alloy including: 0.02 % C, 1.31 % Mn, 0.02 % P, 0.001 % S, 0.45 % Si, 9.1 % Ni, and 18.7 % Cr. In an exemplary embodiment, the anisotropy of the predetermined portion of the tubular assembly, prior to the radial expansion and plastic deformation, is about 1.34. In an exemplary embodiment, the yield point of the predetermined portion of the tubular assembly is at most about 46.9 ksi prior to the radial expansion and plastic deformation; and wherein the yield point of the predetermined portion of the tubular assembly is at least about 65.9 ksi after the radial expansion and plastic deformation. In an exemplary embodiment, the yield point of the predetermined portion of the tubular assembly after the radial expansion and plastic deformation is at least about 40 % greater than the yield point of the predetermined portion of the tubular assembly prior to the radial expansion and plastic deformation. In an exemplary embodiment, the anisotropy of the predetermined portion of the tubular assembly, prior to the radial expansion and plastic deformation, is at least about 1.48. In an exemplary embodiment, the yield point of the predetermined portion of the tubular assembly is at most about 57.8 ksi prior to the radial expansion and plastic deformation; and the yield point of the predetermined portion of the tubular assembly is at least about 74.4 ksi after the radial expansion and plastic deformation. In an exemplary embodiment, the yield point of the predetermined portion of the tubular assembly after the radial expansion and plastic deformation is at least about 28 % greater than the yield point of the predetermined portion of the tubular assembly prior to the radial expansion and plastic deformation. In an exemplary embodiment, the anisotropy of the predetermined portion of the tubular assembly, prior to the radial expansion and plastic deformation, is at least about 1.04. In an exemplary embodiment, the anisotropy of the predetermined portion of the tubular assembly, prior to the radial expansion and plastic deformation, is at least about 1.92. In an exemplary embodiment, the anisotropy of the predetermined portion of the tubular assembly, prior to the radial expansion and plastic deformation, is at least about 1.34. In an exemplary embodiment, the anisotropy of the predetermined portion of the tubular assembly, prior to the radial expansion and plastic deformation, ranges from about 1.04 to about 1.92. In an exemplary embodiment, the yield point of the predetermined portion of the tubular assembly, prior to the radial expansion and plastic deformation, ranges from about 47.6 ksi to about 61.7 ksi. In an exemplary embodiment, the expandability coefficient of the predetermined

portion of the tubular assembly, prior to the radial expansion and plastic deformation, is greater than 0.12. In an exemplary embodiment, the expandability coefficient of the predetermined portion of the tubular assembly is greater than the expandability coefficient of the other portion of the tubular assembly. In an exemplary embodiment, the tubular assembly includes a wellbore casing, a pipeline, or a structural support. In an exemplary embodiment, the carbon content of the predetermined portion of the tubular assembly is less than or equal to 0.12 percent; and wherein the carbon equivalent value for the predetermined portion of the tubular assembly is less than 0.21. In an exemplary embodiment, the carbon content of the predetermined portion of the tubular assembly is greater than 0.12 percent; and wherein the carbon equivalent value for the predetermined portion of the tubular assembly is less than 0.36. In an exemplary embodiment, a yield point of an inner tubular portion of at least a portion of the tubular assembly is less than a yield point of an outer tubular portion of the portion of the tubular assembly. In an exemplary embodiment, yield point of the inner tubular portion of the tubular body varies as a function of the radial position within the tubular body. In an exemplary embodiment, the yield point of the inner tubular portion of the tubular body varies in an linear fashion as a function of the radial position within the tubular body. In an exemplary embodiment, the yield point of the inner tubular portion of the tubular body varies in an non-linear fashion as a function of the radial position within the tubular body. In an exemplary embodiment, the yield point of the outer tubular portion of the tubular body varies as a function of the radial position within the tubular body. In an exemplary embodiment, the yield point of the outer tubular portion of the tubular body varies in an linear fashion as a function of the radial position within the tubular body. In an exemplary embodiment, the yield point of the outer tubular portion of the tubular body varies in an non-linear fashion as a function of the radial position within the tubular body. In an exemplary embodiment, the yield point of the inner tubular portion of the tubular body varies as a function of the radial position within the tubular body; and wherein the yield point of the outer tubular portion of the tubular body varies as a function of the radial position within the tubular body. In an exemplary embodiment, the yield point of the inner tubular portion of the tubular body varies in a linear fashion as a function of the radial position within the tubular body; and wherein the yield point of the outer tubular portion of the tubular body varies in a linear fashion as a function of the radial position within the tubular body. In an exemplary embodiment, the yield point of the inner tubular portion of the tubular body varies in a linear fashion as a function of the radial position within the tubular body; and wherein the yield point of the outer tubular portion of the tubular body varies in a non-linear fashion as a function of the radial position within the tubular body. In an exemplary embodiment, the yield point of the inner tubular portion of the tubular body varies in a non-linear fashion as a function of the radial position within the tubular body; and wherein the yield point of the outer

tubular portion of the tubular body varies in a linear fashion as a function of the radial position within the tubular body. In an exemplary embodiment, the yield point of the inner tubular portion of the tubular body varies in a non-linear fashion as a function of the radial position within the tubular body; and wherein the yield point of the outer tubular portion of the tubular body varies in a non-linear fashion as a function of the radial position within the tubular body. In an exemplary embodiment, the rate of change of the yield point of the inner tubular portion of the tubular body is different than the rate of change of the yield point of the outer tubular portion of the tubular body. In an exemplary embodiment, the rate of change of the yield point of the inner tubular portion of the tubular body is different than the rate of change of the yield point of the outer tubular portion of the tubular body. In an exemplary embodiment, prior to the radial expansion and plastic deformation, at least a portion of the tubular assembly comprises a microstructure comprising a hard phase structure and a soft phase structure. In an exemplary embodiment, prior to the radial expansion and plastic deformation, at least a portion of the tubular assembly comprises a microstructure comprising a transitional phase structure. In an exemplary embodiment, the hard phase structure comprises martensite. In an exemplary embodiment, the soft phase structure comprises ferrite. In an exemplary embodiment, the transitional phase structure comprises retained austentite. In an exemplary embodiment, the hard phase structure comprises martensite; wherein the soft phase structure comprises ferrite; and wherein the transitional phase structure comprises retained austentite. In an exemplary embodiment, the portion of the tubular assembly comprising a microstructure comprising a hard phase structure and a soft phase structure comprises, by weight percentage, about 0.1% C, about 1.2% Mn, and about 0.3% Si.

[00567] An expandable tubular member has been described that includes a steel alloy including: 0.065 % C, 1.44 % Mn, 0.01 % P, 0.002 % S, 0.24 % Si, 0.01 % Cu, 0.01 % Ni, and 0.02 % Cr. In an exemplary embodiment, a yield point of the tubular member is at most about 46.9 ksi prior to a radial expansion and plastic deformation; and a yield point of the tubular member is at least about 65.9 ksi after the radial expansion and plastic deformation. In an exemplary embodiment, the yield point of the tubular member after the radial expansion and plastic deformation is at least about 40 % greater than the yield point of the tubular member prior to the radial expansion and plastic deformation. In an exemplary embodiment, the anisotropy of the tubular member, prior to a radial expansion and plastic deformation, is about 1.48. In an exemplary embodiment, the tubular member includes a wellbore casing, a pipeline, or a structural support.

[00568] An expandable tubular member has been described that includes a steel alloy including: 0.18 % C, 1.28 % Mn, 0.017 % P, 0.004 % S, 0.29 % Si, 0.01 % Cu, 0.01 % Ni, and 0.03 % Cr. In an exemplary embodiment, a yield point of the tubular member is at most

about 57.8 ksi prior to a radial expansion and plastic deformation; and the yield point of the tubular member is at least about 74.4 ksi after the radial expansion and plastic deformation. In an exemplary embodiment, a yield point of the of the tubular member after a radial expansion and plastic deformation is at least about 28 % greater than the yield point of the tubular member prior to the radial expansion and plastic deformation. In an exemplary embodiment, the anisotropy of the tubular member, prior to a radial expansion and plastic deformation, is about 1.04. In an exemplary embodiment, the tubular member includes a wellbore casing, a pipeline, or a structural support.

[00569] An expandable tubular member has been described that includes a steel alloy including: 0.08 % C, 0.82 % Mn, 0.006 % P, 0.003 % S, 0.30 % Si, 0.16 % Cu, 0.05 % Ni, and 0.05 % Cr. In an exemplary embodiment, the anisotropy of the tubular member, prior to a radial expansion and plastic deformation, is about 1.92. In an exemplary embodiment, the tubular member includes a wellbore casing, a pipeline, or a structural support.

[00570] An expandable tubular member has been described that includes a steel alloy including: 0.02 % C, 1.31 % Mn, 0.02 % P, 0.001 % S, 0.45 % Si, 9.1 % Ni, and 18.7 % Cr. In an exemplary embodiment, the anisotropy of the tubular member, prior to a radial expansion and plastic deformation, is about 1.34. In an exemplary embodiment, the tubular member includes a wellbore casing, a pipeline, or a structural support.

[00571] An expandable tubular member has been described, wherein the yield point of the expandable tubular member is at most about 46.9 ksi prior to a radial expansion and plastic deformation; and wherein the yield point of the expandable tubular member is at least about 65.9 ksi after the radial expansion and plastic deformation. In an exemplary embodiment, the tubular member includes a wellbore casing, a pipeline, or a structural support.

[00572] An expandable tubular member has been described, wherein a yield point of the expandable tubular member after a radial expansion and plastic deformation is at least about 40 % greater than the yield point of the expandable tubular member prior to the radial expansion and plastic deformation. In an exemplary embodiment, the tubular member includes a wellbore casing, a pipeline, or a structural support.

[00573] An expandable tubular member has been described, wherein the anisotropy of the expandable tubular member, prior to the radial expansion and plastic deformation, is at least about 1.48. In an exemplary embodiment, the tubular member includes a wellbore casing, a pipeline, or a structural support.

[00574] An expandable tubular member has been described, wherein the yield point of the expandable tubular member is at most about 57.8 ksi prior to the radial expansion and plastic deformation; and wherein the yield point of the expandable tubular member is at least about 74.4 ksi after the radial expansion and plastic deformation. In an exemplary

embodiment, the tubular member includes a wellbore casing, a pipeline, or a structural support.

[00575] An expandable tubular member has been described, wherein the yield point of the expandable tubular member after a radial expansion and plastic deformation is at least about 28 % greater than the yield point of the expandable tubular member prior to the radial expansion and plastic deformation. In an exemplary embodiment, the tubular member includes a wellbore casing, a pipeline, or a structural support.

[00576] An expandable tubular member has been described, wherein the anisotropy of the expandable tubular member, prior to the radial expansion and plastic deformation, is at least about 1.04. In an exemplary embodiment, the tubular member includes a wellbore casing, a pipeline, or a structural support.

[00577] An expandable tubular member has been described, wherein the anisotropy of the expandable tubular member, prior to the radial expansion and plastic deformation, is at least about 1.92. In an exemplary embodiment, the tubular member includes a wellbore casing, a pipeline, or a structural support.

[00578] An expandable tubular member has been described, wherein the anisotropy of the expandable tubular member, prior to the radial expansion and plastic deformation, is at least about 1.34. In an exemplary embodiment, the tubular member includes a wellbore casing, a pipeline, or a structural support.

[00579] An expandable tubular member has been described, wherein the anisotropy of the expandable tubular member, prior to the radial expansion and plastic deformation, ranges from about 1.04 to about 1.92. In an exemplary embodiment, the tubular member includes a wellbore casing, a pipeline, or a structural support.

[00580] An expandable tubular member has been described, wherein the yield point of the expandable tubular member, prior to the radial expansion and plastic deformation, ranges from about 47.6 ksi to about 61.7 ksi. In an exemplary embodiment, the tubular member includes a wellbore casing, a pipeline, or a structural support.

[00581] An expandable tubular member has been described, wherein the expandability coefficient of the expandable tubular member, prior to the radial expansion and plastic deformation, is greater than 0.12. In an exemplary embodiment, the tubular member includes a wellbore casing, a pipeline, or a structural support.

[00582] An expandable tubular member has been described, wherein the expandability coefficient of the expandable tubular member is greater than the expandability coefficient of another portion of the expandable tubular member. In an exemplary embodiment, the tubular member includes a wellbore casing, a pipeline, or a structural support.

[00583] An expandable tubular member has been described, wherein the tubular member has a higher ductility and a lower yield point prior to a radial expansion and plastic

deformation than after the radial expansion and plastic deformation. In an exemplary embodiment, the tubular member includes a wellbore casing, a pipeline, or a structural support.

[00584] A method of radially expanding and plastically deforming a tubular assembly including a first tubular member coupled to a second tubular member has been described that includes radially expanding and plastically deforming the tubular assembly within a preexisting structure; and using less power to radially expand each unit length of the first tubular member than to radially expand each unit length of the second tubular member. In an exemplary embodiment, the tubular member includes a wellbore casing, a pipeline, or a structural support.

[00585] A system for radially expanding and plastically deforming a tubular assembly including a first tubular member coupled to a second tubular member has been described that includes means for radially expanding the tubular assembly within a preexisting structure; and means for using less power to radially expand each unit length of the first tubular member than required to radially expand each unit length of the second tubular member. In an exemplary embodiment, the tubular member includes a wellbore casing, a pipeline, or a structural support.

[00586] A method of manufacturing a tubular member has been described that includes processing a tubular member until the tubular member is characterized by one or more intermediate characteristics; positioning the tubular member within a preexisting structure; and processing the tubular member within the preexisting structure until the tubular member is characterized one or more final characteristics. In an exemplary embodiment, the tubular member includes a wellbore casing, a pipeline, or a structural support. In an exemplary embodiment, the preexisting structure includes a wellbore that traverses a subterranean formation. In an exemplary embodiment, the characteristics are selected from a group consisting of yield point and ductility. In an exemplary embodiment, processing the tubular member within the preexisting structure until the tubular member is characterized one or more final characteristics includes: radially expanding and plastically deforming the tubular member within the preexisting structure.

[00587] An apparatus has been described that includes an expandable tubular assembly; and an expansion device coupled to the expandable tubular assembly; wherein a predetermined portion of the expandable tubular assembly has a lower yield point than another portion of the expandable tubular assembly. In an exemplary embodiment, the expansion device includes a rotary expansion device, an axially displaceable expansion device, a reciprocating expansion device, a hydroforming expansion device, and/or an impulsive force expansion device. In an exemplary embodiment, the predetermined portion of the tubular assembly has a higher ductility and a lower yield point than another portion of

the expandable tubular assembly. In an exemplary embodiment, the predetermined portion of the tubular assembly has a higher ductility than another portion of the expandable tubular assembly. In an exemplary embodiment, the predetermined portion of the tubular assembly has a lower yield point than another portion of the expandable tubular assembly. In an exemplary embodiment, the predetermined portion of the tubular assembly includes an end portion of the tubular assembly. In an exemplary embodiment, the predetermined portion of the tubular assembly includes a plurality of predetermined portions of the tubular assembly. In an exemplary embodiment, the predetermined portion of the tubular assembly includes a plurality of spaced apart predetermined portions of the tubular assembly. In an exemplary embodiment, the other portion of the tubular assembly includes an end portion of the tubular assembly. In an exemplary embodiment, the other portion of the tubular assembly includes a plurality of other portions of the tubular assembly. In an exemplary embodiment, the other portion of the tubular assembly includes a plurality of spaced apart other portions of the tubular assembly. In an exemplary embodiment, the tubular assembly includes a plurality of tubular members coupled to one another by corresponding tubular couplings. In an exemplary embodiment, the tubular couplings comprise the predetermined portions of the tubular assembly; and wherein the tubular members comprise the other portion of the tubular assembly. In an exemplary embodiment, one or more of the tubular couplings comprise the predetermined portions of the tubular assembly. In an exemplary embodiment, one or more of the tubular members comprise the predetermined portions of the tubular assembly. In an exemplary embodiment, the predetermined portion of the tubular assembly defines one or more openings. In an exemplary embodiment, one or more of the openings comprise slots. In an exemplary embodiment, the anisotropy for the predetermined portion of the tubular assembly is greater than 1 In an exemplary embodiment, the anisotropy for the predetermined portion of the tubular assembly is greater than 1. In an exemplary embodiment, the strain hardening exponent for the predetermined portion of the tubular assembly is greater than 0.12. In an exemplary embodiment, the anisotropy for the predetermined portion of the tubular assembly is greater than 1; and wherein the strain hardening exponent for the predetermined portion of the tubular assembly is greater than 0.12. In an exemplary embodiment, the predetermined portion of the tubular assembly includes a first steel alloy including: 0.065 % C, 1.44 % Mn, 0.01 % P, 0.002 % S, 0.24 % Si, 0.01 % Cu, 0.01 % Ni, and 0.02 % Cr. In an exemplary embodiment, the yield point of the predetermined portion of the tubular assembly is at most about 46.9 ksi. In an exemplary embodiment, the anisotropy of the predetermined portion of the tubular assembly is about 1.48. In an exemplary embodiment, the predetermined portion of the tubular assembly includes a second steel alloy including: 0.18 % C, 1.28 % Mn, 0.017 % P, 0.004 % S, 0.29 % Si, 0.01 % Cu, 0.01 % Ni, and 0.03 % Cr. In an exemplary embodiment, the yield point of

the predetermined portion of the tubular assembly is at most about 57.8 ksi. In an exemplary embodiment, the anisotropy of the predetermined portion of the tubular assembly is about 1.04. In an exemplary embodiment, the predetermined portion of the tubular assembly includes a third steel alloy including: 0.08 % C, 0.82 % Mn, 0.006 % P, 0.003 % S, 0.30 % Si, 0.16 % Cu, 0.05 % Ni, and 0.05 % Cr. In an exemplary embodiment, the anisotropy of the predetermined portion of the tubular assembly is about 1.92. In an exemplary embodiment, the predetermined portion of the tubular assembly includes a fourth steel alloy including: 0.02 % C, 1.31 % Mn, 0.02 % P, 0.001 % S, 0.45 % Si, 9.1 % Ni, and 18.7 % Cr. In an exemplary embodiment, the anisotropy of the predetermined portion of the tubular assembly is at least about 1.34. In an exemplary embodiment, the yield point of the predetermined portion of the tubular assembly is at most about 46.9 ksi. In an exemplary embodiment, the anisotropy of the predetermined portion of the tubular assembly is at least about 1.48. In an exemplary embodiment, the yield point of the predetermined portion of the tubular assembly is at most about 57.8 ksi. In an exemplary embodiment, the anisotropy of the predetermined portion of the tubular assembly is at least about 1.04. In an exemplary embodiment, the anisotropy of the predetermined portion of the tubular assembly is at least about 1.92. In an exemplary embodiment, the anisotropy of the predetermined portion of the tubular assembly is at least about 1.34. In an exemplary embodiment, the anisotropy of the predetermined portion of the tubular assembly ranges from about 1.04 to about 1.92. In an exemplary embodiment, the yield point of the predetermined portion of the tubular assembly ranges from about 47.6 ksi to about 61.7 ksi. In an exemplary embodiment, the expandability coefficient of the predetermined portion of the tubular assembly is greater than 0.12. In an exemplary embodiment, the expandability coefficient of the predetermined portion of the tubular assembly is greater than the expandability coefficient of the other portion of the tubular assembly. In an exemplary embodiment, the tubular assembly includes a wellbore casing, a pipeline, or a structural support. In an exemplary embodiment, the carbon content of the predetermined portion of the tubular assembly is less than or equal to 0.12 percent; and wherein the carbon equivalent value for the predetermined portion of the tubular assembly is less than 0.21. In an exemplary embodiment, the carbon content of the predetermined portion of the tubular assembly is greater than 0.12 percent; and wherein the carbon equivalent value for the predetermined portion of the tubular assembly is less than 0.36. In an exemplary embodiment, a yield point of an inner tubular portion of at least a portion of the tubular assembly is less than a yield point of an outer tubular portion of the portion of the tubular assembly. In an exemplary embodiment, the yield point of the inner tubular portion of the tubular body varies as a function of the radial position within the tubular body. In an exemplary embodiment, the yield point of the inner tubular portion of the tubular body varies in an linear fashion as a function of the radial position within the tubular body. In

an exemplary embodiment, the yield point of the inner tubular portion of the tubular body varies in an non-linear fashion as a function of the radial position within the tubular body. In an exemplary embodiment, the yield point of the outer tubular portion of the tubular body varies as a function of the radial position within the tubular body. In an exemplary embodiment, the yield point of the outer tubular portion of the tubular body varies in an linear fashion as a function of the radial position within the tubular body. In an exemplary embodiment, the yield point of the outer tubular portion of the tubular body varies in an non-linear fashion as a function of the radial position within the tubular body. In an exemplary embodiment, the yield point of the inner tubular portion of the tubular body varies as a function of the radial position within the tubular body; and wherein the yield point of the outer tubular portion of the tubular body varies as a function of the radial position within the tubular body. In an exemplary embodiment, the yield point of the inner tubular portion of the tubular body varies in a linear fashion as a function of the radial position within the tubular body; and wherein the yield point of the outer tubular portion of the tubular body varies in a linear fashion as a function of the radial position within the tubular body. In an exemplary embodiment, the yield point of the inner tubular portion of the tubular body varies in a linear fashion as a function of the radial position within the tubular body; and wherein the yield point of the outer tubular portion of the tubular body varies in a non-linear fashion as a function of the radial position within the tubular body. In an exemplary embodiment, the yield point of the inner tubular portion of the tubular body varies in a non-linear fashion as a function of the radial position within the tubular body; and wherein the yield point of the outer tubular portion of the tubular body varies in a linear fashion as a function of the radial position within the tubular body. In an exemplary embodiment, the yield point of the inner tubular portion of the tubular body varies in a non-linear fashion as a function of the radial position within the tubular body; and wherein the yield point of the outer tubular portion of the tubular body varies in a non-linear fashion as a function of the radial position within the tubular body. In an exemplary embodiment, the rate of change of the yield point of the inner tubular portion of the tubular body is different than the rate of change of the yield point of the outer tubular portion of the tubular body. In an exemplary embodiment, the rate of change of the yield point of the inner tubular portion of the tubular body is different than the rate of change of the yield point of the outer tubular portion of the tubular body. In an exemplary embodiment, at least a portion of the tubular assembly comprises a microstructure comprising a hard phase structure and a soft phase structure. In an exemplary embodiment, prior to the radial expansion and plastic deformation, at least a portion of the tubular assembly comprises a microstructure comprising a transitional phase structure. In an exemplary embodiment, wherein the hard phase structure comprises martensite. In an exemplary embodiment, wherein the soft phase structure comprises ferrite. In an exemplary

embodiment, wherein the transitional phase structure comprises retained austentite. In an exemplary embodiment, the hard phase structure comprises martensite; wherein the soft phase structure comprises ferrite; and wherein the transitional phase structure comprises retained austentite. In an exemplary embodiment, the portion of the tubular assembly comprising a microstructure comprising a hard phase structure and a soft phase structure comprises, by weight percentage, about 0.1% C, about 1.2% Mn, and about 0.3% Si. In an exemplary embodiment, at least a portion of the tubular assembly comprises a microstructure comprising a hard phase structure and a soft phase structure. In an exemplary embodiment, the portion of the tubular assembly comprises, by weight percentage, 0.065% C, 1.44% Mn, 0.01% P, 0.002% S, 0.24% Si, 0.01% Cu, 0.01% Ni, 0.02% Cr, 0.05% V, 0.01% Mo, 0.01% Nb, and 0.01%Ti. In an exemplary embodiment, the portion of the tubular assembly comprises, by weight percentage, 0.18% C, 1.28% Mn, 0.017% P, 0.004% S, 0.29% Si, 0.01% Cu, 0.01% Ni, 0.03% Cr, 0.04% V, 0.01% Mo, 0.03% Nb, and 0.01%Ti. In an exemplary embodiment, the portion of the tubular assembly comprises, by weight percentage, 0.08% C, 0.82% Mn, 0.006% P, 0.003% S, 0.30% Si, 0.06% Cu, 0.05% Ni, 0.05% Cr, 0.03% V, 0.03% Mo, 0.01% Nb, and 0.01%Ti. In an exemplary embodiment, the portion of the tubular assembly comprises a microstructure comprising one or more of the following: martensite, pearlite, vanadium carbide, nickel carbide, or titanium carbide. In an exemplary embodiment, the portion of the tubular assembly comprises a microstructure comprising one or more of the following: pearlite or pearlite striation. In an exemplary embodiment, the portion of the tubular assembly comprises a microstructure comprising one or more of the following: grain pearlite, widmanstatten martensite, vanadium carbide, nickel carbide, or titanium carbide. In an exemplary embodiment, the portion of the tubular assembly comprises a microstructure comprising one or more of the following: ferrite, grain pearlite, or martensite. In an exemplary embodiment, the portion of the tubular assembly comprises a microstructure comprising one or more of the following: ferrite, martensite, or bainite. In an exemplary embodiment, the portion of the tubular assembly comprises a microstructure comprising one or more of the following: bainite, pearlite, or ferrite. In an exemplary embodiment, the portion of the tubular assembly comprises a yield strength of about 67ksi and a tensile strength of about 95 ksi. In an exemplary embodiment, the portion of the tubular assembly comprises a yield strength of about 82 ksi and a tensile strength of about 130 ksi. In an exemplary embodiment, the portion of the tubular assembly comprises a yield strength of about 60 ksi and a tensile strength of about 97 ksi.

[00588] An expandable tubular member has been described, wherein a yield point of the expandable tubular member after a radial expansion and plastic deformation is at least about 5.8 % greater than the yield point of the expandable tubular member prior to the radial

expansion and plastic deformation. In an exemplary embodiment, the tubular member includes a wellbore casing, a pipeline, or a structural support.

[00589] A method of determining the expandability of a selected tubular member has been described that includes determining an anisotropy value for the selected tubular member, determining a strain hardening value for the selected tubular member; and multiplying the anisotropy value times the strain hardening value to generate an expandability value for the selected tubular member. In an exemplary embodiment, an anisotropy value greater than 0.12 indicates that the tubular member is suitable for radial expansion and plastic deformation. In an exemplary embodiment, the tubular member includes a wellbore casing, a pipeline, or a structural support.

[00590] A method of radially expanding and plastically deforming tubular members has been described that includes selecting a tubular member; determining an anisotropy value for the selected tubular member; determining a strain hardening value for the selected tubular member; multiplying the anisotropy value times the strain hardening value to generate an expandability value for the selected tubular member; and if the anisotropy value is greater than 0.12, then radially expanding and plastically deforming the selected tubular member. In an exemplary embodiment, the tubular member includes a wellbore casing, a pipeline, or a structural support. In an exemplary embodiment, radially expanding and plastically deforming the selected tubular member includes: inserting the selected tubular member into a preexisting structure; and then radially expanding and plastically deforming the selected tubular member. In an exemplary embodiment, the preexisting structure includes a wellbore that traverses a subterranean formation.

[00591] A radially expandable multiple tubular member apparatus has been described that includes a first tubular member; a second tubular member engaged with the first tubular member forming a joint; a sleeve overlapping and coupling the first and second tubular members at the joint; the sleeve having opposite tapered ends and a flange engaged in a recess formed in an adjacent tubular member; and one of the tapered ends being a surface formed on the flange. In an exemplary embodiment, the recess includes a tapered wall in mating engagement with the tapered end formed on the flange. In an exemplary embodiment, the sleeve includes a flange at each tapered end and each tapered end is formed on a respective flange. In an exemplary embodiment, each tubular member includes a recess. In an exemplary embodiment, each flange is engaged in a respective one of the recesses. In an exemplary embodiment, each recess includes a tapered wall in mating engagement with the tapered end formed on a respective one of the flanges.

[00592] A method of joining radially expandable multiple tubular members has also been described that includes providing a first tubular member; engaging a second tubular member with the first tubular member to form a joint; providing a sleeve having opposite

tapered ends and a flange, one of the tapered ends being a surface formed on the flange; and mounting the sleeve for overlapping and coupling the first and second tubular members at the joint, wherein the flange is engaged in a recess formed in an adjacent one of the tubular members. In an exemplary embodiment, the method further includes providing a tapered wall in the recess for mating engagement with the tapered end formed on the flange. In an exemplary embodiment, the method further includes providing a flange at each tapered end wherein each tapered end is formed on a respective flange. In an exemplary embodiment, the method further includes providing a recess in each tubular member. In an exemplary embodiment, the method further includes engaging each flange in a respective one of the recesses. In an exemplary embodiment, the method further includes providing a tapered wall in each recess for mating engagement with the tapered end formed on a respective one of the flanges.

[00593] A radially expandable multiple tubular member apparatus has been described that includes a first tubular member; a second tubular member engaged with the first tubular member forming a joint; and a sleeve overlapping and coupling the first and second tubular members at the joint; wherein at least a portion of the sleeve is comprised of a frangible material.

[00594] A radially expandable multiple tubular member apparatus has been described that includes a first tubular member; a second tubular member engaged with the first tubular member forming a joint; and a sleeve overlapping and coupling the first and second tubular members at the joint; wherein the wall thickness of the sleeve is variable.

[00595] A method of joining radially expandable multiple tubular members has been described that includes providing a first tubular member; engaging a second tubular member with the first tubular member to form a joint; providing a sleeve comprising a frangible material; and mounting the sleeve for overlapping and coupling the first and second tubular members at the joint.

[00596] A method of joining radially expandable multiple tubular members has been described that includes providing a first tubular member; engaging a second tubular member with the first tubular member to form a joint; providing a sleeve comprising a variable wall thickness; and mounting the sleeve for overlapping and coupling the first and second tubular members at the joint.

[00597] An expandable tubular assembly has been described that includes a first tubular member; a second tubular member coupled to the first tubular member; and means for increasing the axial compression loading capacity of the coupling between the first and second tubular members before and after a radial expansion and plastic deformation of the first and second tubular members.

[00598] An expandable tubular assembly has been described that includes a first tubular member; a second tubular member coupled to the first tubular member; and means for increasing the axial tension loading capacity of the coupling between the first and second tubular members before and after a radial expansion and plastic deformation of the first and second tubular members.

[00599] An expandable tubular assembly has been described that includes a first tubular member; a second tubular member coupled to the first tubular member; and means for increasing the axial compression and tension loading capacity of the coupling between the first and second tubular members before and after a radial expansion and plastic deformation of the first and second tubular members.

[00600] An expandable tubular assembly has been described that includes a first tubular member; a second tubular member coupled to the first tubular member; and means for avoiding stress risers in the coupling between the first and second tubular members before and after a radial expansion and plastic deformation of the first and second tubular members.

[00601] An expandable tubular assembly has been described that includes a first tubular member; a second tubular member coupled to the first tubular member; and means for inducing stresses at selected portions of the coupling between the first and second tubular members before and after a radial expansion and plastic deformation of the first and second tubular members.

[00602] In several exemplary embodiments of the apparatus described above, the sleeve is circumferentially tensioned; and wherein the first and second tubular members are circumferentially compressed.

[00603] In several exemplary embodiments of the method described above, the method further includes maintaining the sleeve in circumferential tension; and maintaining the first and second tubular members in circumferential compression before, during, and/or after the radial expansion and plastic deformation of the first and second tubular members.

[00604] An expandable tubular assembly has been described that includes a first tubular member, a second tubular member coupled to the first tubular member, a first threaded connection for coupling a portion of the first and second tubular members, a second threaded connection spaced apart from the first threaded connection for coupling another portion of the first and second tubular members, a tubular sleeve coupled to and receiving end portions of the first and second tubular members, and a sealing element positioned between the first and second spaced apart threaded connections for sealing an interface between the first and second tubular member, wherein the sealing element is positioned within an annulus defined between the first and second tubular members. In an exemplary embodiment, the annulus is at least partially defined by an irregular surface. In

an exemplary embodiment, the annulus is at least partially defined by a toothed surface. In an exemplary embodiment, the sealing element comprises an elastomeric material. In an exemplary embodiment, the sealing element comprises a metallic material. In an exemplary embodiment, the sealing element comprises an elastomeric and a metallic material.

[00605] A method of joining radially expandable multiple tubular members has been described that includes providing a first tubular member, providing a second tubular member, providing a sleeve, mounting the sleeve for overlapping and coupling the first and second tubular members, threadably coupling the first and second tubular members at a first location, threadably coupling the first and second tubular members at a second location spaced apart from the first location, and sealing an interface between the first and second tubular members between the first and second locations using a compressible sealing element. In an exemplary embodiment, the sealing element includes an irregular surface. In an exemplary embodiment, the sealing element includes a toothed surface. In an exemplary embodiment, the sealing element comprises an elastomeric material. In an exemplary embodiment, the sealing element comprises a metallic material. In an exemplary embodiment, the sealing element comprises an elastomeric and a metallic material.

[00606] An expandable tubular assembly has been described that includes a first tubular member, a second tubular member coupled to the first tubular member, a first threaded connection for coupling a portion of the first and second tubular members, a second threaded connection spaced apart from the first threaded connection for coupling another portion of the first and second tubular members, and a plurality of spaced apart tubular sleeves coupled to and receiving end portions of the first and second tubular members. In an exemplary embodiment, at least one of the tubular sleeves is positioned in opposing relation to the first threaded connection; and wherein at least one of the tubular sleeves is positioned in opposing relation to the second threaded connection. In an exemplary embodiment, at least one of the tubular sleeves is not positioned in opposing relation to the first and second threaded connections.

[00607] A method of joining radially expandable multiple tubular members has been described that includes providing a first tubular member, providing a second tubular member, threadably coupling the first and second tubular members at a first location, threadably coupling the first and second tubular members at a second location spaced apart from the first location, providing a plurality of sleeves, and mounting the sleeves at spaced apart locations for overlapping and coupling the first and second tubular members. In an exemplary embodiment, at least one of the tubular sleeves is positioned in opposing relation to the first threaded coupling; and wherein at least one of the tubular sleeves is positioned in opposing relation to the second threaded coupling. In an exemplary embodiment, at least

one of the tubular sleeves is not positioned in opposing relation to the first and second threaded couplings.

[00608] An expandable tubular assembly has been described that includes a first tubular member, a second tubular member coupled to the first tubular member, and a plurality of spaced apart tubular sleeves coupled to and receiving end portions of the first and second tubular members.

[00609] A method of joining radially expandable multiple tubular members has been described that includes providing a first tubular member, providing a second tubular member, providing a plurality of sleeves, coupling the first and second tubular members, and mounting the sleeves at spaced apart locations for overlapping and coupling the first and second tubular members.

[00610] An expandable tubular assembly has been described that includes a first tubular member, a second tubular member coupled to the first tubular member, a threaded connection for coupling a portion of the first and second tubular members, and a tubular sleeves coupled to and receiving end portions of the first and second tubular members, wherein at least a portion of the threaded connection is upset. In an exemplary embodiment, at least a portion of tubular sleeve penetrates the first tubular member.

[00611] A method of joining radially expandable multiple tubular members has been described that includes providing a first tubular member, providing a second tubular member, threadably coupling the first and second tubular members, and upsetting the threaded coupling. In an exemplary embodiment, the first tubular member further comprises an annular extension extending therefrom, and the flange of the sleeve defines an annular recess for receiving and mating with the annular extension of the first tubular member. In an exemplary embodiment, the first tubular member further comprises an annular extension extending therefrom; and the flange of the sleeve defines an annular recess for receiving and mating with the annular extension of the first tubular member.

[00612] A radially expandable multiple tubular member apparatus has been described that includes a first tubular member, a second tubular member engaged with the first tubular member forming a joint, a sleeve overlapping and coupling the first and second tubular members at the joint, and one or more stress concentrators for concentrating stresses in the joint. In an exemplary embodiment, one or more of the stress concentrators comprises one or more external grooves defined in the first tubular member. In an exemplary embodiment, one or more of the stress concentrators comprises one or more internal grooves defined in the second tubular member. In an exemplary embodiment, one or more of the stress concentrators comprises one or more openings defined in the sleeve. In an exemplary embodiment, one or more of the stress concentrators comprises one or more external grooves defined in the first tubular member; and one or more of the stress concentrators

comprises one or more internal grooves defined in the second tubular member. In an exemplary embodiment, one or more of the stress concentrators comprises one or more external grooves defined in the first tubular member; and one or more of the stress concentrators comprises one or more openings defined in the sleeve. In an exemplary embodiment, one or more of the stress concentrators comprises one or more internal grooves defined in the second tubular member; and one or more of the stress concentrators comprises one or more openings defined in the sleeve. In an exemplary embodiment, one or more of the stress concentrators comprises one or more external grooves defined in the first tubular member; wherein one or more of the stress concentrators comprises one or more internal grooves defined in the second tubular member; and wherein one or more of the stress concentrators comprises one or more openings defined in the sleeve.

[00613] A method of joining radially expandable multiple tubular members has been described that includes providing a first tubular member, engaging a second tubular member with the first tubular member to form a joint, providing a sleeve having opposite tapered ends and a flange, one of the tapered ends being a surface formed on the flange, and concentrating stresses within the joint. In an exemplary embodiment, concentrating stresses within the joint comprises using the first tubular member to concentrate stresses within the joint. In an exemplary embodiment, concentrating stresses within the joint comprises using the second tubular member to concentrate stresses within the joint. In an exemplary embodiment, concentrating stresses within the joint comprises using the sleeve to concentrate stresses within the joint. In an exemplary embodiment, concentrating stresses within the joint comprises using the first tubular member and the second tubular member to concentrate stresses within the joint. In an exemplary embodiment, concentrating stresses within the joint comprises using the first tubular member and the sleeve to concentrate stresses within the joint. In an exemplary embodiment, concentrating stresses within the joint comprises using the second tubular member and the sleeve to concentrate stresses within the joint. In an exemplary embodiment, concentrating stresses within the joint comprises using the first tubular member, the second tubular member, and the sleeve to concentrate stresses within the joint.

[00614] A system for radially expanding and plastically deforming a first tubular member coupled to a second tubular member by a mechanical connection has been described that includes means for radially expanding the first and second tubular members, and means for maintaining portions of the first and second tubular member in circumferential compression following the radial expansion and plastic deformation of the first and second tubular members.

[00615] A system for radially expanding and plastically deforming a first tubular member coupled to a second tubular member by a mechanical connection has been

described that includes means for radially expanding the first and second tubular members; and means for concentrating stresses within the mechanical connection during the radial expansion and plastic deformation of the first and second tubular members.

[00616] A system for radially expanding and plastically deforming a first tubular member coupled to a second tubular member by a mechanical connection has been described that includes means for radially expanding the first and second tubular members; means for maintaining portions of the first and second tubular member in circumferential compression following the radial expansion and plastic deformation of the first and second tubular members; and means for concentrating stresses within the mechanical connection during the radial expansion and plastic deformation of the first and second tubular members.

[00617] A radially expandable tubular member apparatus has been described that includes a first tubular member; a second tubular member engaged with the first tubular member forming a joint; and a sleeve overlapping and coupling the first and second tubular members at the joint; wherein, prior to a radial expansion and plastic deformation of the apparatus, a predetermined portion of the apparatus has a lower yield point than another portion of the apparatus. In an exemplary embodiment, the carbon content of the predetermined portion of the apparatus is less than or equal to 0.12 percent; and wherein the carbon equivalent value for the predetermined portion of the apparatus is less than 0.21. In an exemplary embodiment, the carbon content of the predetermined portion of the apparatus is greater than 0.12 percent; and wherein the carbon equivalent value for the predetermined portion of the apparatus is less than 0.36. In an exemplary embodiment, the apparatus further includes means for maintaining portions of the first and second tubular member in circumferential compression following the radial expansion and plastic deformation of the first and second tubular members. In an exemplary embodiment, the apparatus further includes means for concentrating stresses within the mechanical connection during the radial expansion and plastic deformation of the first and second tubular members. In an exemplary embodiment, the apparatus further includes means for maintaining portions of the first and second tubular member in circumferential compression following the radial expansion and plastic deformation of the first and second tubular members; and means for concentrating stresses within the mechanical connection during the radial expansion and plastic deformation of the first and second tubular members. In an exemplary embodiment, the apparatus further includes one or more stress concentrators for concentrating stresses in the joint. In an exemplary embodiment, one or more of the stress concentrators comprises one or more external grooves defined in the first tubular member. In an exemplary embodiment, one or more of the stress concentrators comprises one or more internal grooves defined in the second tubular member. In an exemplary embodiment, one or more of the stress concentrators comprises one or more openings defined in the

sleeve. In an exemplary embodiment, one or more of the stress concentrators comprises one or more external grooves defined in the first tubular member; and wherein one or more of the stress concentrators comprises one or more internal grooves defined in the second tubular member. In an exemplary embodiment, one or more of the stress concentrators comprises one or more external grooves defined in the first tubular member; and wherein one or more of the stress concentrators comprises one or more openings defined in the sleeve. In an exemplary embodiment, one or more of the stress concentrators comprises one or more internal grooves defined in the second tubular member; and wherein one or more of the stress concentrators comprises one or more openings defined in the sleeve. In an exemplary embodiment, one or more of the stress concentrators comprises one or more external grooves defined in the first tubular member; wherein one or more of the stress concentrators comprises one or more internal grooves defined in the second tubular member; and wherein one or more of the stress concentrators comprises one or more openings defined in the sleeve. In an exemplary embodiment, the first tubular member further comprises an annular extension extending therefrom; and wherein the flange of the sleeve defines an annular recess for receiving and mating with the annular extension of the first tubular member. In an exemplary embodiment, the apparatus further includes a threaded connection for coupling a portion of the first and second tubular members; wherein at least a portion of the threaded connection is upset. In an exemplary embodiment, at least a portion of tubular sleeve penetrates the first tubular member. In an exemplary embodiment, the apparatus further includes means for increasing the axial compression loading capacity of the joint between the first and second tubular members before and after a radial expansion and plastic deformation of the first and second tubular members. In an exemplary embodiment, the apparatus further includes means for increasing the axial tension loading capacity of the joint between the first and second tubular members before and after a radial expansion and plastic deformation of the first and second tubular members. In an exemplary embodiment, the apparatus further includes means for increasing the axial compression and tension loading capacity of the joint between the first and second tubular members before and after a radial expansion and plastic deformation of the first and second tubular members. In an exemplary embodiment, the apparatus further includes means for avoiding stress risers in the joint between the first and second tubular members before and after a radial expansion and plastic deformation of the first and second tubular members. In an exemplary embodiment, the apparatus further includes means for inducing stresses at selected portions of the coupling between the first and second tubular members before and after a radial expansion and plastic deformation of the first and second tubular members. In an exemplary embodiment, the sleeve is circumferentially tensioned; and wherein the first and second tubular members are circumferentially compressed. In an

exemplary embodiment, the means for increasing the axial compression loading capacity of the coupling between the first and second tubular members before and after a radial expansion and plastic deformation of the first and second tubular members is circumferentially tensioned; and wherein the first and second tubular members are circumferentially compressed. In an exemplary embodiment, the means for increasing the axial tension loading capacity of the coupling between the first and second tubular members before and after a radial expansion and plastic deformation of the first and second tubular members is circumferentially tensioned; and wherein the first and second tubular members are circumferentially compressed. In an exemplary embodiment, the means for increasing the axial compression and tension loading capacity of the coupling between the first and second tubular members before and after a radial expansion and plastic deformation of the first and second tubular members is circumferentially tensioned; and wherein the first and second tubular members are circumferentially compressed. In an exemplary embodiment, the means for avoiding stress risers in the coupling between the first and second tubular members before and after a radial expansion and plastic deformation of the first and second tubular members is circumferentially tensioned; and wherein the first and second tubular members are circumferentially compressed. In an exemplary embodiment, the means for inducing stresses at selected portions of the coupling between the first and second tubular members before and after a radial expansion and plastic deformation of the first and second tubular members is circumferentially tensioned; and wherein the first and second tubular members are circumferentially compressed. In an exemplary embodiment, at least a portion of the sleeve is comprised of a frangible material. In an exemplary embodiment, the wall thickness of the sleeve is variable. In an exemplary embodiment, the predetermined portion of the apparatus has a higher ductility and a lower yield point prior to the radial expansion and plastic deformation than after the radial expansion and plastic deformation. In an exemplary embodiment, the predetermined portion of the apparatus has a higher ductility prior to the radial expansion and plastic deformation than after the radial expansion and plastic deformation. In an exemplary embodiment, the predetermined portion of the apparatus has a lower yield point prior to the radial expansion and plastic deformation than after the radial expansion and plastic deformation. In an exemplary embodiment, the predetermined portion of the apparatus has a larger inside diameter after the radial expansion and plastic deformation than other portions of the tubular assembly. In an exemplary embodiment, the sleeve is circumferentially tensioned; and wherein the first and second tubular members are circumferentially compressed. In an exemplary embodiment, the sleeve is circumferentially tensioned; and wherein the first and second tubular members are circumferentially compressed. In an exemplary embodiment, the apparatus further includes positioning another apparatus within the preexisting structure in overlapping relation

to the apparatus; and radially expanding and plastically deforming the other apparatus within the preexisting structure; wherein, prior to the radial expansion and plastic deformation of the apparatus, a predetermined portion of the other apparatus has a lower yield point than another portion of the other apparatus. In an exemplary embodiment, the inside diameter of the radially expanded and plastically deformed other portion of the apparatus is equal to the inside diameter of the radially expanded and plastically deformed other portion of the other apparatus. In an exemplary embodiment, the predetermined portion of the apparatus comprises an end portion of the apparatus. In an exemplary embodiment, the predetermined portion of the apparatus comprises a plurality of predetermined portions of the apparatus. In an exemplary embodiment, the predetermined portion of the apparatus comprises a plurality of spaced apart predetermined portions of the apparatus. In an exemplary embodiment, the other portion of the apparatus comprises an end portion of the apparatus. In an exemplary embodiment, the other portion of the apparatus comprises a plurality of other portions of the apparatus. In an exemplary embodiment, the other portion of the apparatus comprises a plurality of spaced apart other portions of the apparatus. In an exemplary embodiment, the apparatus comprises a plurality of tubular members coupled to one another by corresponding tubular couplings. In an exemplary embodiment, the tubular couplings comprise the predetermined portions of the apparatus; and wherein the tubular members comprise the other portion of the apparatus. In an exemplary embodiment, one or more of the tubular couplings comprise the predetermined portions of the apparatus. In an exemplary embodiment, one or more of the tubular members comprise the predetermined portions of the apparatus. In an exemplary embodiment, the predetermined portion of the apparatus defines one or more openings. In an exemplary embodiment, one or more of the openings comprise slots. In an exemplary embodiment, the anisotropy for the predetermined portion of the apparatus is greater than 1. In an exemplary embodiment, the anisotropy for the predetermined portion of the apparatus is greater than 1. In an exemplary embodiment, the strain hardening exponent for the predetermined portion of the apparatus is greater than 0.12. In an exemplary embodiment, the anisotropy for the predetermined portion of the apparatus is greater than 1; and wherein the strain hardening exponent for the predetermined portion of the apparatus is greater than 0.12. In an exemplary embodiment, the predetermined portion of the apparatus comprises a first steel alloy comprising: 0.065 % C, 1.44 % Mn, 0.01 % P, 0.002 % S, 0.24 % Si, 0.01 % Cu, 0.01 % Ni, and 0.02 % Cr. In an exemplary embodiment, the yield point of the predetermined portion of the apparatus is at most about 46.9 ksi prior to the radial expansion and plastic deformation; and wherein the yield point of the predetermined portion of the apparatus is at least about 65.9 ksi after the radial expansion and plastic deformation. In an exemplary embodiment, the yield point of the predetermined portion of the apparatus after the radial expansion and plastic

deformation is at least about 40 % greater than the yield point of the predetermined portion of the apparatus prior to the radial expansion and plastic deformation. In an exemplary embodiment, the anisotropy of the predetermined portion of the apparatus, prior to the radial expansion and plastic deformation, is about 1.48. In an exemplary embodiment, the predetermined portion of the apparatus comprises a second steel alloy comprising: 0.18 % C, 1.28 % Mn, 0.017 % P, 0.004 % S, 0.29 % Si, 0.01 % Cu, 0.01 % Ni, and 0.03 % Cr. In an exemplary embodiment, the yield point of the predetermined portion of the apparatus is at most about 57.8 ksi prior to the radial expansion and plastic deformation; and wherein the yield point of the predetermined portion of the apparatus is at least about 74.4 ksi after the radial expansion and plastic deformation. In an exemplary embodiment, the yield point of the predetermined portion of the apparatus after the radial expansion and plastic deformation is at least about 28 % greater than the yield point of the predetermined portion of the apparatus prior to the radial expansion and plastic deformation. In an exemplary embodiment, the anisotropy of the predetermined portion of the apparatus, prior to the radial expansion and plastic deformation, is about 1.04. In an exemplary embodiment, the predetermined portion of the apparatus comprises a third steel alloy comprising: 0.08 % C, 0.82 % Mn, 0.006 % P, 0.003 % S, 0.30 % Si, 0.16 % Cu, 0.05 % Ni, and 0.05 % Cr. In an exemplary embodiment, the anisotropy of the predetermined portion of the apparatus, prior to the radial expansion and plastic deformation, is about 1.92. In an exemplary embodiment, the predetermined portion of the apparatus comprises a fourth steel alloy comprising: 0.02 % C, 1.31 % Mn, 0.02 % P, 0.001 % S, 0.45 % Si, 9.1 % Ni, and 18.7 % Cr. In an exemplary embodiment, the anisotropy of the predetermined portion of the apparatus, prior to the radial expansion and plastic deformation, is about 1.34. In an exemplary embodiment, the yield point of the predetermined portion of the apparatus is at most about 46.9 ksi prior to the radial expansion and plastic deformation; and wherein the yield point of the predetermined portion of the apparatus is at least about 65.9 ksi after the radial expansion and plastic deformation. In an exemplary embodiment, the yield point of the predetermined portion of the apparatus after the radial expansion and plastic deformation is at least about 40 % greater than the yield point of the predetermined portion of the apparatus prior to the radial expansion and plastic deformation. In an exemplary embodiment, the anisotropy of the predetermined portion of the apparatus, prior to the radial expansion and plastic deformation, is at least about 1.48. In an exemplary embodiment, the yield point of the predetermined portion of the apparatus is at most about 57.8 ksi prior to the radial expansion and plastic deformation; and wherein the yield point of the predetermined portion of the apparatus is at least about 74.4 ksi after the radial expansion and plastic deformation. In an exemplary embodiment, the yield point of the predetermined portion of the apparatus after the radial expansion and plastic deformation is at least about 28 % greater than the yield

point of the predetermined portion of the apparatus prior to the radial expansion and plastic deformation. In an exemplary embodiment, the anisotropy of the predetermined portion of the apparatus, prior to the radial expansion and plastic deformation, is at least about 1.04. In an exemplary embodiment, the anisotropy of the predetermined portion of the apparatus, prior to the radial expansion and plastic deformation, is at least about 1.92. In an exemplary embodiment, the anisotropy of the predetermined portion of the apparatus, prior to the radial expansion and plastic deformation, is at least about 1.34. In an exemplary embodiment, the anisotropy of the predetermined portion of the apparatus, prior to the radial expansion and plastic deformation, ranges from about 1.04 to about 1.92. In an exemplary embodiment, the yield point of the predetermined portion of the apparatus, prior to the radial expansion and plastic deformation, ranges from about 47.6 ksi to about 61.7 ksi. In an exemplary embodiment, the expandability coefficient of the predetermined portion of the apparatus, prior to the radial expansion and plastic deformation, is greater than 0.12. In an exemplary embodiment, the expandability coefficient of the predetermined portion of the apparatus is greater than the expandability coefficient of the other portion of the apparatus. In an exemplary embodiment, the apparatus comprises a wellbore casing. In an exemplary embodiment, the apparatus comprises a pipeline. In an exemplary embodiment, the apparatus comprises a structural support.

[00618] A radially expandable tubular member apparatus has been described that includes a first tubular member; a second tubular member engaged with the first tubular member forming a joint; a sleeve overlapping and coupling the first and second tubular members at the joint; the sleeve having opposite tapered ends and a flange engaged in a recess formed in an adjacent tubular member; and one of the tapered ends being a surface formed on the flange; wherein, prior to a radial expansion and plastic deformation of the apparatus, a predetermined portion of the apparatus has a lower yield point than another portion of the apparatus. In an exemplary embodiment, the recess includes a tapered wall in mating engagement with the tapered end formed on the flange. In an exemplary embodiment, the sleeve includes a flange at each tapered end and each tapered end is formed on a respective flange. In an exemplary embodiment, each tubular member includes a recess. In an exemplary embodiment, each flange is engaged in a respective one of the recesses. In an exemplary embodiment, each recess includes a tapered wall in mating engagement with the tapered end formed on a respective one of the flanges. In an exemplary embodiment, the predetermined portion of the apparatus has a higher ductility and a lower yield point prior to the radial expansion and plastic deformation than after the radial expansion and plastic deformation. In an exemplary embodiment, the predetermined portion of the apparatus has a higher ductility prior to the radial expansion and plastic deformation than after the radial expansion and plastic deformation. In an exemplary

embodiment, the predetermined portion of the apparatus has a lower yield point prior to the radial expansion and plastic deformation than after the radial expansion and plastic deformation. In an exemplary embodiment, the predetermined portion of the apparatus has a larger inside diameter after the radial expansion and plastic deformation than other portions of the tubular assembly. In an exemplary embodiment, the apparatus further includes positioning another apparatus within the preexisting structure in overlapping relation to the apparatus; and radially expanding and plastically deforming the other apparatus within the preexisting structure; wherein, prior to the radial expansion and plastic deformation of the apparatus, a predetermined portion of the other apparatus has a lower yield point than another portion of the other apparatus. In an exemplary embodiment, the inside diameter of the radially expanded and plastically deformed other portion of the apparatus is equal to the inside diameter of the radially expanded and plastically deformed other portion of the other apparatus. In an exemplary embodiment, the predetermined portion of the apparatus comprises an end portion of the apparatus. In an exemplary embodiment, the predetermined portion of the apparatus comprises a plurality of predetermined portions of the apparatus. In an exemplary embodiment, the predetermined portion of the apparatus comprises a plurality of spaced apart predetermined portions of the apparatus. In an exemplary embodiment, the other portion of the apparatus comprises an end portion of the apparatus. In an exemplary embodiment, the other portion of the apparatus comprises a plurality of other portions of the apparatus. In an exemplary embodiment, the other portion of the apparatus comprises a plurality of spaced apart other portions of the apparatus. In an exemplary embodiment, the apparatus comprises a plurality of tubular members coupled to one another by corresponding tubular couplings. In an exemplary embodiment, the tubular couplings comprise the predetermined portions of the apparatus; and wherein the tubular members comprise the other portion of the apparatus. In an exemplary embodiment, one or more of the tubular couplings comprise the predetermined portions of the apparatus. In an exemplary embodiment, one or more of the tubular members comprise the predetermined portions of the apparatus. In an exemplary embodiment, the predetermined portion of the apparatus defines one or more openings. In an exemplary embodiment, one or more of the openings comprise slots. In an exemplary embodiment, the anisotropy for the predetermined portion of the apparatus is greater than 1. In an exemplary embodiment, the anisotropy for the predetermined portion of the apparatus is greater than 1. In an exemplary embodiment, the strain hardening exponent for the predetermined portion of the apparatus is greater than 0.12. In an exemplary embodiment, the anisotropy for the predetermined portion of the apparatus is greater than 1; and wherein the strain hardening exponent for the predetermined portion of the apparatus is greater than 0.12. In an exemplary embodiment, the predetermined portion of the apparatus comprises a first steel alloy comprising: 0.065 %

C, 1.44 % Mn, 0.01 % P, 0.002 % S, 0.24 % Si, 0.01 % Cu, 0.01 % Ni, and 0.02 % Cr. In an exemplary embodiment, the yield point of the predetermined portion of the apparatus is at most about 46.9 ksi prior to the radial expansion and plastic deformation; and wherein the yield point of the predetermined portion of the apparatus is at least about 65.9 ksi after the radial expansion and plastic deformation. In an exemplary embodiment, the yield point of the predetermined portion of the apparatus after the radial expansion and plastic deformation is at least about 40 % greater than the yield point of the predetermined portion of the apparatus prior to the radial expansion and plastic deformation. In an exemplary embodiment, the anisotropy of the predetermined portion of the apparatus, prior to the radial expansion and plastic deformation, is about 1.48. In an exemplary embodiment, the predetermined portion of the apparatus comprises a second steel alloy comprising: 0.18 % C, 1.28 % Mn, 0.017 % P, 0.004 % S, 0.29 % Si, 0.01 % Cu, 0.01 % Ni, and 0.03 % Cr. In an exemplary embodiment, the yield point of the predetermined portion of the apparatus is at most about 57.8 ksi prior to the radial expansion and plastic deformation; and wherein the yield point of the predetermined portion of the apparatus is at least about 74.4 ksi after the radial expansion and plastic deformation. In an exemplary embodiment, the yield point of the predetermined portion of the apparatus after the radial expansion and plastic deformation is at least about 28 % greater than the yield point of the predetermined portion of the apparatus prior to the radial expansion and plastic deformation. In an exemplary embodiment, the anisotropy of the predetermined portion of the apparatus, prior to the radial expansion and plastic deformation, is about 1.04. In an exemplary embodiment, the predetermined portion of the apparatus comprises a third steel alloy comprising: 0.08 % C, 0.82 % Mn, 0.006 % P, 0.003 % S, 0.30 % Si, 0.16 % Cu, 0.05 % Ni, and 0.05 % Cr. In an exemplary embodiment, the anisotropy of the predetermined portion of the apparatus, prior to the radial expansion and plastic deformation, is about 1.92. In an exemplary embodiment, the predetermined portion of the apparatus comprises a fourth steel alloy comprising: 0.02 % C, 1.31 % Mn, 0.02 % P, 0.001 % S, 0.45 % Si, 9.1 % Ni, and 18.7 % Cr. In an exemplary embodiment, the anisotropy of the predetermined portion of the apparatus, prior to the radial expansion and plastic deformation, is about 1.34. In an exemplary embodiment, the yield point of the predetermined portion of the apparatus is at most about 46.9 ksi prior to the radial expansion and plastic deformation; and wherein the yield point of the predetermined portion of the apparatus is at least about 65.9 ksi after the radial expansion and plastic deformation. In an exemplary embodiment, the yield point of the predetermined portion of the apparatus after the radial expansion and plastic deformation is at least about 40 % greater than the yield point of the predetermined portion of the apparatus prior to the radial expansion and plastic deformation. In an exemplary embodiment, the anisotropy of the predetermined portion of the apparatus, prior to the radial expansion and plastic

deformation, is at least about 1.48. In an exemplary embodiment, the yield point of the predetermined portion of the apparatus is at most about 57.8 ksi prior to the radial expansion and plastic deformation; and wherein the yield point of the predetermined portion of the apparatus is at least about 74.4 ksi after the radial expansion and plastic deformation. In an exemplary embodiment, the yield point of the predetermined portion of the apparatus after the radial expansion and plastic deformation is at least about 28 % greater than the yield point of the predetermined portion of the apparatus prior to the radial expansion and plastic deformation. In an exemplary embodiment, the anisotropy of the predetermined portion of the apparatus, prior to the radial expansion and plastic deformation, is at least about 1.04. In an exemplary embodiment, the anisotropy of the predetermined portion of the apparatus, prior to the radial expansion and plastic deformation, is at least about 1.92. In an exemplary embodiment, the anisotropy of the predetermined portion of the apparatus, prior to the radial expansion and plastic deformation, is at least about 1.34. In an exemplary embodiment, the anisotropy of the predetermined portion of the apparatus, prior to the radial expansion and plastic deformation, ranges from about 1.04 to about 1.92. In an exemplary embodiment, the yield point of the predetermined portion of the apparatus, prior to the radial expansion and plastic deformation, ranges from about 47.6 ksi to about 61.7 ksi. In an exemplary embodiment, the expandability coefficient of the predetermined portion of the apparatus, prior to the radial expansion and plastic deformation, is greater than 0.12. In an exemplary embodiment, the expandability coefficient of the predetermined portion of the apparatus is greater than the expandability coefficient of the other portion of the apparatus. In an exemplary embodiment, the apparatus comprises a wellbore casing. In an exemplary embodiment, the apparatus comprises a pipeline. In an exemplary embodiment, the apparatus comprises a structural support.

[00619] A method of joining radially expandable tubular members has been provided that includes: providing a first tubular member; engaging a second tubular member with the first tubular member to form a joint; providing a sleeve; mounting the sleeve for overlapping and coupling the first and second tubular members at the joint; wherein the first tubular member, the second tubular member, and the sleeve define a tubular assembly; and radially expanding and plastically deforming the tubular assembly; wherein, prior to the radial expansion and plastic deformation, a predetermined portion of the tubular assembly has a lower yield point than another portion of the tubular assembly. In an exemplary embodiment, the carbon content of the predetermined portion of the tubular assembly is less than or equal to 0.12 percent; and wherein the carbon equivalent value for the predetermined portion of the tubular assembly is less than 0.21. In an exemplary embodiment, the carbon content of the predetermined portion of the tubular assembly is greater than 0.12 percent; and wherein the carbon equivalent value for the predetermined portion of the tubular assembly is less

than 0.36. In an exemplary embodiment, the method further includes: maintaining portions of the first and second tubular member in circumferential compression following a radial expansion and plastic deformation of the first and second tubular members. In an exemplary embodiment, the method further includes: concentrating stresses within the joint during a radial expansion and plastic deformation of the first and second tubular members. In an exemplary embodiment, the method further includes: maintaining portions of the first and second tubular member in circumferential compression following a radial expansion and plastic deformation of the first and second tubular members; and concentrating stresses within the joint during a radial expansion and plastic deformation of the first and second tubular members. In an exemplary embodiment, the method further includes: concentrating stresses within the joint. In an exemplary embodiment, concentrating stresses within the joint comprises using the first tubular member to concentrate stresses within the joint. In an exemplary embodiment, concentrating stresses within the joint comprises using the second tubular member to concentrate stresses within the joint. In an exemplary embodiment, concentrating stresses within the joint comprises using the sleeve to concentrate stresses within the joint. In an exemplary embodiment, concentrating stresses within the joint comprises using the first tubular member and the second tubular member to concentrate stresses within the joint. In an exemplary embodiment, concentrating stresses within the joint comprises using the first tubular member and the sleeve to concentrate stresses within the joint. In an exemplary embodiment, concentrating stresses within the joint comprises using the second tubular member and the sleeve to concentrate stresses within the joint. In an exemplary embodiment, concentrating stresses within the joint comprises using the first tubular member, the second tubular member, and the sleeve to concentrate stresses within the joint. In an exemplary embodiment, at least a portion of the sleeve is comprised of a frangible material. In an exemplary embodiment, the sleeve comprises a variable wall thickness. In an exemplary embodiment, the method further includes maintaining the sleeve in circumferential tension; and maintaining the first and second tubular members in circumferential compression. In an exemplary embodiment, the method further includes maintaining the sleeve in circumferential tension; and maintaining the first and second tubular members in circumferential compression. In an exemplary embodiment, the method further includes: maintaining the sleeve in circumferential tension; and maintaining the first and second tubular members in circumferential compression. In an exemplary embodiment, the method further includes: threadably coupling the first and second tubular members at a first location; threadably coupling the first and second tubular members at a second location spaced apart from the first location; providing a plurality of sleeves; and mounting the sleeves at spaced apart locations for overlapping and coupling the first and second tubular members. In an exemplary embodiment, at least one of the tubular sleeves is positioned in

opposing relation to the first threaded coupling; and wherein at least one of the tubular sleeves is positioned in opposing relation to the second threaded coupling. In an exemplary embodiment, at least one of the tubular sleeves is not positioned in opposing relation to the first and second threaded couplings. In an exemplary embodiment, the method further includes: threadably coupling the first and second tubular members; and upsetting the threaded coupling. In an exemplary embodiment, the first tubular member further comprises an annular extension extending therefrom; and wherein the flange of the sleeve defines an annular recess for receiving and mating with the annular extension of the first tubular member. In an exemplary embodiment, the predetermined portion of the tubular assembly has a higher ductility and a lower yield point prior to the radial expansion and plastic deformation than after the radial expansion and plastic deformation. In an exemplary embodiment, the predetermined portion of the tubular assembly has a higher ductility prior to the radial expansion and plastic deformation than after the radial expansion and plastic deformation. In an exemplary embodiment, the predetermined portion of the tubular assembly has a lower yield point prior to the radial expansion and plastic deformation than after the radial expansion and plastic deformation. In an exemplary embodiment, the predetermined portion of the tubular assembly has a larger inside diameter after the radial expansion and plastic deformation than the other portion of the tubular assembly. In an exemplary embodiment, the method further includes: positioning another tubular assembly within the preexisting structure in overlapping relation to the tubular assembly; and radially expanding and plastically deforming the other tubular assembly within the preexisting structure; wherein, prior to the radial expansion and plastic deformation of the tubular assembly, a predetermined portion of the other tubular assembly has a lower yield point than another portion of the other tubular assembly. In an exemplary embodiment, the inside diameter of the radially expanded and plastically deformed other portion of the tubular assembly is equal to the inside diameter of the radially expanded and plastically deformed other portion of the other tubular assembly. In an exemplary embodiment, the predetermined portion of the tubular assembly comprises an end portion of the tubular assembly. In an exemplary embodiment, the predetermined portion of the tubular assembly comprises a plurality of predetermined portions of the tubular assembly. In an exemplary embodiment, the predetermined portion of the tubular assembly comprises a plurality of spaced apart predetermined portions of the tubular assembly. In an exemplary embodiment, the other portion of the tubular assembly comprises an end portion of the tubular assembly. In an exemplary embodiment, the other portion of the tubular assembly comprises a plurality of other portions of the tubular assembly. In an exemplary embodiment, the other portion of the tubular assembly comprises a plurality of spaced apart other portions of the tubular assembly. In an exemplary embodiment, the tubular assembly comprises a plurality of

tubular members coupled to one another by corresponding tubular couplings. In an exemplary embodiment, the tubular couplings comprise the predetermined portions of the tubular assembly; and wherein the tubular members comprise the other portion of the tubular assembly. In an exemplary embodiment, one or more of the tubular couplings comprise the predetermined portions of the tubular assembly. In an exemplary embodiment, one or more of the tubular members comprise the predetermined portions of the tubular assembly. In an exemplary embodiment, the predetermined portion of the tubular assembly defines one or more openings. In an exemplary embodiment, one or more of the openings comprise slots. In an exemplary embodiment, the anisotropy for the predetermined portion of the tubular assembly is greater than 1. In an exemplary embodiment, the anisotropy for the predetermined portion of the tubular assembly is greater than 1. In an exemplary embodiment, the strain hardening exponent for the predetermined portion of the tubular assembly is greater than 0.12. In an exemplary embodiment, the anisotropy for the predetermined portion of the tubular assembly is greater than 1; and wherein the strain hardening exponent for the predetermined portion of the tubular assembly is greater than 0.12. In an exemplary embodiment, the predetermined portion of the tubular assembly comprises a first steel alloy comprising: 0.065 % C, 1.44 % Mn, 0.01 % P, 0.002 % S, 0.24 % Si, 0.01 % Cu, 0.01 % Ni, and 0.02 % Cr. In an exemplary embodiment, the yield point of the predetermined portion of the tubular assembly is at most about 46.9 ksi prior to the radial expansion and plastic deformation; and wherein the yield point of the predetermined portion of the tubular assembly is at least about 65.9 ksi after the radial expansion and plastic deformation. In an exemplary embodiment, the yield point of the predetermined portion of the tubular assembly after the radial expansion and plastic deformation is at least about 40 % greater than the yield point of the predetermined portion of the tubular assembly prior to the radial expansion and plastic deformation. In an exemplary embodiment, the anisotropy of the predetermined portion of the tubular assembly, prior to the radial expansion and plastic deformation, is about 1.48. In an exemplary embodiment, the predetermined portion of the tubular assembly comprises a second steel alloy comprising: 0.18 % C, 1.28 % Mn, 0.017 % P, 0.004 % S, 0.29 % Si, 0.01 % Cu, 0.01 % Ni, and 0.03 % Cr. In an exemplary embodiment, the yield point of the predetermined portion of the tubular assembly is at most about 57.8 ksi prior to the radial expansion and plastic deformation; and wherein the yield point of the predetermined portion of the tubular assembly is at least about 74.4 ksi after the radial expansion and plastic deformation. In an exemplary embodiment, the yield point of the predetermined portion of the tubular assembly after the radial expansion and plastic deformation is at least about 28 % greater than the yield point of the predetermined portion of the tubular assembly prior to the radial expansion and plastic deformation. In an exemplary embodiment, the anisotropy of the predetermined portion of the tubular assembly,

prior to the radial expansion and plastic deformation, is about 1.04. In an exemplary embodiment, the predetermined portion of the tubular assembly comprises a third steel alloy comprising: 0.08 % C, 0.82 % Mn, 0.006 % P, 0.003 % S, 0.30 % Si, 0.16 % Cu, 0.05 % Ni, and 0.05 % Cr. In an exemplary embodiment, the anisotropy of the predetermined portion of the tubular assembly, prior to the radial expansion and plastic deformation, is about 1.92. In an exemplary embodiment, the predetermined portion of the tubular assembly comprises a fourth steel alloy comprising: 0.02 % C, 1.31 % Mn, 0.02 % P, 0.001 % S, 0.45 % Si, 9.1 % Ni, and 18.7 % Cr. In an exemplary embodiment, the anisotropy of the predetermined portion of the tubular assembly, prior to the radial expansion and plastic deformation, is about 1.34. In an exemplary embodiment, the yield point of the predetermined portion of the tubular assembly is at most about 46.9 ksi prior to the radial expansion and plastic deformation; and wherein the yield point of the predetermined portion of the tubular assembly is at least about 65.9 ksi after the radial expansion and plastic deformation. In an exemplary embodiment, the yield point of the predetermined portion of the tubular assembly after the radial expansion and plastic deformation is at least about 40 % greater than the yield point of the predetermined portion of the tubular assembly prior to the radial expansion and plastic deformation. In an exemplary embodiment, the anisotropy of the predetermined portion of the tubular assembly, prior to the radial expansion and plastic deformation, is at least about 1.48. In an exemplary embodiment, the yield point of the predetermined portion of the tubular assembly is at most about 57.8 ksi prior to the radial expansion and plastic deformation; and wherein the yield point of the predetermined portion of the tubular assembly is at least about 74.4 ksi after the radial expansion and plastic deformation. In an exemplary embodiment, the yield point of the predetermined portion of the tubular assembly after the radial expansion and plastic deformation is at least about 28 % greater than the yield point of the predetermined portion of the tubular assembly prior to the radial expansion and plastic deformation. In an exemplary embodiment, the anisotropy of the predetermined portion of the tubular assembly, prior to the radial expansion and plastic deformation, is at least about 1.04. In an exemplary embodiment, the anisotropy of the predetermined portion of the tubular assembly, prior to the radial expansion and plastic deformation, is at least about 1.92. In an exemplary embodiment, the anisotropy of the predetermined portion of the tubular assembly, prior to the radial expansion and plastic deformation, is at least about 1.34. In an exemplary embodiment, the anisotropy of the predetermined portion of the tubular assembly, prior to the radial expansion and plastic deformation, ranges from about 1.04 to about 1.92. In an exemplary embodiment, the yield point of the predetermined portion of the tubular assembly, prior to the radial expansion and plastic deformation, ranges from about 47.6 ksi to about 61.7 ksi. In an exemplary embodiment, the expandability coefficient of the predetermined portion of the tubular assembly, prior to the radial expansion

and plastic deformation, is greater than 0.12. In an exemplary embodiment, the expandability coefficient of the predetermined portion of the tubular assembly is greater than the expandability coefficient of the other portion of the tubular assembly. In an exemplary embodiment, the tubular assembly comprises a wellbore casing. In an exemplary embodiment, the tubular assembly comprises a pipeline. In an exemplary embodiment, the tubular assembly comprises a structural support.

[00620] A method of joining radially expandable tubular members has been described that includes: providing a first tubular member; engaging a second tubular member with the first tubular member to form a joint; providing a sleeve having opposite tapered ends and a flange, one of the tapered ends being a surface formed on the flange; mounting the sleeve for overlapping and coupling the first and second tubular members at the joint, wherein the flange is engaged in a recess formed in an adjacent one of the tubular members; wherein the first tubular member, the second tubular member, and the sleeve define a tubular assembly; and radially expanding and plastically deforming the tubular assembly; wherein, prior to the radial expansion and plastic deformation, a predetermined portion of the tubular assembly has a lower yield point than another portion of the tubular assembly. In an exemplary embodiment, the method further includes: providing a tapered wall in the recess for mating engagement with the tapered end formed on the flange. In an exemplary embodiment, the method further includes: providing a flange at each tapered end wherein each tapered end is formed on a respective flange. In an exemplary embodiment, the method further includes: providing a recess in each tubular member. In an exemplary embodiment, the method further includes: engaging each flange in a respective one of the recesses. In an exemplary embodiment, the method further includes: providing a tapered wall in each recess for mating engagement with the tapered end formed on a respective one of the flanges. In an exemplary embodiment, the predetermined portion of the tubular assembly has a higher ductility and a lower yield point prior to the radial expansion and plastic deformation than after the radial expansion and plastic deformation. In an exemplary embodiment, the predetermined portion of the tubular assembly has a higher ductility prior to the radial expansion and plastic deformation than after the radial expansion and plastic deformation. In an exemplary embodiment, the predetermined portion of the tubular assembly has a lower yield point prior to the radial expansion and plastic deformation than after the radial expansion and plastic deformation. In an exemplary embodiment, the predetermined portion of the tubular assembly has a larger inside diameter after the radial expansion and plastic deformation than the other portion of the tubular assembly. In an exemplary embodiment, the method further includes: positioning another tubular assembly within the preexisting structure in overlapping relation to the tubular assembly; and radially expanding and plastically deforming the other tubular assembly within the preexisting

structure; wherein, prior to the radial expansion and plastic deformation of the tubular assembly, a predetermined portion of the other tubular assembly has a lower yield point than another portion of the other tubular assembly. In an exemplary embodiment, the inside diameter of the radially expanded and plastically deformed other portion of the tubular assembly is equal to the inside diameter of the radially expanded and plastically deformed other portion of the other tubular assembly. In an exemplary embodiment, the predetermined portion of the tubular assembly comprises an end portion of the tubular assembly. In an exemplary embodiment, the predetermined portion of the tubular assembly comprises a plurality of predetermined portions of the tubular assembly. In an exemplary embodiment, the predetermined portion of the tubular assembly comprises a plurality of spaced apart predetermined portions of the tubular assembly. In an exemplary embodiment, the other portion of the tubular assembly comprises an end portion of the tubular assembly. In an exemplary embodiment, the other portion of the tubular assembly comprises a plurality of other portions of the tubular assembly. In an exemplary embodiment, the other portion of the tubular assembly comprises a plurality of spaced apart other portions of the tubular assembly. In an exemplary embodiment, the tubular assembly comprises a plurality of tubular members coupled to one another by corresponding tubular couplings. In an exemplary embodiment, the tubular couplings comprise the predetermined portions of the tubular assembly; and wherein the tubular members comprise the other portion of the tubular assembly. In an exemplary embodiment, one or more of the tubular couplings comprise the predetermined portions of the tubular assembly. In an exemplary embodiment, one or more of the tubular members comprise the predetermined portions of the tubular assembly. In an exemplary embodiment, the predetermined portion of the tubular assembly defines one or more openings. In an exemplary embodiment, one or more of the openings comprise slots. In an exemplary embodiment, the anisotropy for the predetermined portion of the tubular assembly is greater than 1. In an exemplary embodiment, the anisotropy for the predetermined portion of the tubular assembly is greater than 1. In an exemplary embodiment, the strain hardening exponent for the predetermined portion of the tubular assembly is greater than 0.12. In an exemplary embodiment, the anisotropy for the predetermined portion of the tubular assembly is greater than 1; and wherein the strain hardening exponent for the predetermined portion of the tubular assembly is greater than 0.12. In an exemplary embodiment, the predetermined portion of the tubular assembly comprises a first steel alloy comprising: 0.065 % C, 1.44 % Mn, 0.01 % P, 0.002 % S, 0.24 % Si, 0.01 % Cu, 0.01 % Ni, and 0.02 % Cr. In an exemplary embodiment, the yield point of the predetermined portion of the tubular assembly is at most about 46.9 ksi prior to the radial expansion and plastic deformation; and wherein the yield point of the predetermined portion of the tubular assembly is at least about 65.9 ksi after the radial expansion and plastic

deformation. In an exemplary embodiment, the yield point of the predetermined portion of the tubular assembly after the radial expansion and plastic deformation is at least about 40 % greater than the yield point of the predetermined portion of the tubular assembly prior to the radial expansion and plastic deformation. In an exemplary embodiment, the anisotropy of the predetermined portion of the tubular assembly, prior to the radial expansion and plastic deformation, is about 1.48. In an exemplary embodiment, the predetermined portion of the tubular assembly comprises a second steel alloy comprising: 0.18 % C, 1.28 % Mn, 0.017 % P, 0.004 % S, 0.29 % Si, 0.01 % Cu, 0.01 % Ni, and 0.03 % Cr. In an exemplary embodiment, the yield point of the predetermined portion of the tubular assembly is at most about 57.8 ksi prior to the radial expansion and plastic deformation; and wherein the yield point of the predetermined portion of the tubular assembly is at least about 74.4 ksi after the radial expansion and plastic deformation. In an exemplary embodiment, the yield point of the predetermined portion of the tubular assembly after the radial expansion and plastic deformation is at least about 28 % greater than the yield point of the predetermined portion of the tubular assembly prior to the radial expansion and plastic deformation. In an exemplary embodiment, the anisotropy of the predetermined portion of the tubular assembly, prior to the radial expansion and plastic deformation, is about 1.04. In an exemplary embodiment, the predetermined portion of the tubular assembly comprises a third steel alloy comprising: 0.08 % C, 0.82 % Mn, 0.006 % P, 0.003 % S, 0.30 % Si, 0.16 % Cu, 0.05 % Ni, and 0.05 % Cr. In an exemplary embodiment, the anisotropy of the predetermined portion of the tubular assembly, prior to the radial expansion and plastic deformation, is about 1.92. In an exemplary embodiment, the predetermined portion of the tubular assembly comprises a fourth steel alloy comprising: 0.02 % C, 1.31 % Mn, 0.02 % P, 0.001 % S, 0.45 % Si, 9.1 % Ni, and 18.7 % Cr. In an exemplary embodiment, the anisotropy of the predetermined portion of the tubular assembly, prior to the radial expansion and plastic deformation, is about 1.34. In an exemplary embodiment, the yield point of the predetermined portion of the tubular assembly is at most about 46.9 ksi prior to the radial expansion and plastic deformation; and wherein the yield point of the predetermined portion of the tubular assembly is at least about 65.9 ksi after the radial expansion and plastic deformation. In an exemplary embodiment, the yield point of the predetermined portion of the tubular assembly after the radial expansion and plastic deformation is at least about 40 % greater than the yield point of the predetermined portion of the tubular assembly prior to the radial expansion and plastic deformation. In an exemplary embodiment, the anisotropy of the predetermined portion of the tubular assembly, prior to the radial expansion and plastic deformation, is at least about 1.48. In an exemplary embodiment, the yield point of the predetermined portion of the tubular assembly is at most about 57.8 ksi prior to the radial expansion and plastic deformation; and wherein the yield point of the predetermined portion of the tubular

assembly is at least about 74.4 ksi after the radial expansion and plastic deformation. In an exemplary embodiment, the yield point of the predetermined portion of the tubular assembly after the radial expansion and plastic deformation is at least about 28 % greater than the yield point of the predetermined portion of the tubular assembly prior to the radial expansion and plastic deformation. In an exemplary embodiment, the anisotropy of the predetermined portion of the tubular assembly, prior to the radial expansion and plastic deformation, is at least about 1.04. In an exemplary embodiment, the anisotropy of the predetermined portion of the tubular assembly, prior to the radial expansion and plastic deformation, is at least about 1.92. In an exemplary embodiment, the anisotropy of the predetermined portion of the tubular assembly, prior to the radial expansion and plastic deformation, is at least about 1.34. In an exemplary embodiment, the anisotropy of the predetermined portion of the tubular assembly, prior to the radial expansion and plastic deformation, ranges from about 1.04 to about 1.92. In an exemplary embodiment, the yield point of the predetermined portion of the tubular assembly, prior to the radial expansion and plastic deformation, ranges from about 47.6 ksi to about 61.7 ksi. In an exemplary embodiment, the expandability coefficient of the predetermined portion of the tubular assembly, prior to the radial expansion and plastic deformation, is greater than 0.12. In an exemplary embodiment, the expandability coefficient of the predetermined portion of the tubular assembly is greater than the expandability coefficient of the other portion of the tubular assembly. In an exemplary embodiment, the tubular assembly comprises a wellbore casing. In an exemplary embodiment, the tubular assembly comprises a pipeline. In an exemplary embodiment, the tubular assembly comprises a structural support.

[00621] An expandable tubular assembly has been described that includes a first tubular member; a second tubular member coupled to the first tubular member; a first threaded connection for coupling a portion of the first and second tubular members; a second threaded connection spaced apart from the first threaded connection for coupling another portion of the first and second tubular members; a tubular sleeve coupled to and receiving end portions of the first and second tubular members; and a sealing element positioned between the first and second spaced apart threaded connections for sealing an interface between the first and second tubular member; wherein the sealing element is positioned within an annulus defined between the first and second tubular members; and wherein, prior to a radial expansion and plastic deformation of the assembly, a predetermined portion of the assembly has a lower yield point than another portion of the apparatus. In an exemplary embodiment, the predetermined portion of the assembly has a higher ductility and a lower yield point prior to the radial expansion and plastic deformation than after the radial expansion and plastic deformation. In an exemplary embodiment, the predetermined portion of the assembly has a higher ductility prior to the radial expansion and

plastic deformation than after the radial expansion and plastic deformation. In an exemplary embodiment, the predetermined portion of the assembly has a lower yield point prior to the radial expansion and plastic deformation than after the radial expansion and plastic deformation. In an exemplary embodiment, the predetermined portion of the assembly has a larger inside diameter after the radial expansion and plastic deformation than other portions of the tubular assembly. In an exemplary embodiment, the assembly further includes: positioning another assembly within the preexisting structure in overlapping relation to the assembly; and radially expanding and plastically deforming the other assembly within the preexisting structure; wherein, prior to the radial expansion and plastic deformation of the assembly, a predetermined portion of the other assembly has a lower yield point than another portion of the other assembly. In an exemplary embodiment, the inside diameter of the radially expanded and plastically deformed other portion of the assembly is equal to the inside diameter of the radially expanded and plastically deformed other portion of the other assembly. In an exemplary embodiment, the predetermined portion of the assembly comprises an end portion of the assembly. In an exemplary embodiment, the predetermined portion of the assembly comprises a plurality of predetermined portions of the assembly. In an exemplary embodiment, the predetermined portion of the assembly comprises a plurality of spaced apart predetermined portions of the assembly. In an exemplary embodiment, the other portion of the assembly comprises an end portion of the assembly. In an exemplary embodiment, the other portion of the assembly comprises a plurality of other portions of the assembly. In an exemplary embodiment, the other portion of the assembly comprises a plurality of spaced apart other portions of the assembly. In an exemplary embodiment, the assembly comprises a plurality of tubular members coupled to one another by corresponding tubular couplings. In an exemplary embodiment, the tubular couplings comprise the predetermined portions of the assembly; and wherein the tubular members comprise the other portion of the assembly. In an exemplary embodiment, one or more of the tubular couplings comprise the predetermined portions of the assembly. In an exemplary embodiment, one or more of the tubular members comprise the predetermined portions of the assembly. In an exemplary embodiment, the predetermined portion of the assembly defines one or more openings. In an exemplary embodiment, one or more of the openings comprise slots. In an exemplary embodiment, the anisotropy for the predetermined portion of the assembly is greater than 1. In an exemplary embodiment, the anisotropy for the predetermined portion of the assembly is greater than 1. In an exemplary embodiment, the strain hardening exponent for the predetermined portion of the assembly is greater than 0.12. In an exemplary embodiment, the anisotropy for the predetermined portion of the assembly is greater than 1; and wherein the strain hardening exponent for the predetermined portion of the assembly is greater than 0.12. In an exemplary embodiment,

the predetermined portion of the assembly comprises a first steel alloy comprising: 0.065 % C, 1.44 % Mn, 0.01 % P, 0.002 % S, 0.24 % Si, 0.01 % Cu, 0.01 % Ni, and 0.02 % Cr. In an exemplary embodiment, the yield point of the predetermined portion of the assembly is at most about 46.9 ksi prior to the radial expansion and plastic deformation; and wherein the yield point of the predetermined portion of the assembly is at least about 65.9 ksi after the radial expansion and plastic deformation. In an exemplary embodiment, the yield point of the predetermined portion of the assembly after the radial expansion and plastic deformation is at least about 40 % greater than the yield point of the predetermined portion of the assembly prior to the radial expansion and plastic deformation. In an exemplary embodiment, the anisotropy of the predetermined portion of the assembly, prior to the radial expansion and plastic deformation, is about 1.48. In an exemplary embodiment, the predetermined portion of the assembly comprises a second steel alloy comprising: 0.18 % C, 1.28 % Mn, 0.017 % P, 0.004 % S, 0.29 % Si, 0.01 % Cu, 0.01 % Ni, and 0.03 % Cr. In an exemplary embodiment, the yield point of the predetermined portion of the assembly is at most about 57.8 ksi prior to the radial expansion and plastic deformation; and wherein the yield point of the predetermined portion of the assembly is at least about 74.4 ksi after the radial expansion and plastic deformation. In an exemplary embodiment, the yield point of the predetermined portion of the assembly after the radial expansion and plastic deformation is at least about 28 % greater than the yield point of the predetermined portion of the assembly prior to the radial expansion and plastic deformation. In an exemplary embodiment, the anisotropy of the predetermined portion of the assembly, prior to the radial expansion and plastic deformation, is about 1.04. In an exemplary embodiment, the predetermined portion of the assembly comprises a third steel alloy comprising: 0.08 % C, 0.82 % Mn, 0.006 % P, 0.003 % S, 0.30 % Si, 0.16 % Cu, 0.05 % Ni, and 0.05 % Cr. In an exemplary embodiment, the anisotropy of the predetermined portion of the assembly, prior to the radial expansion and plastic deformation, is about 1.92. In an exemplary embodiment, the predetermined portion of the assembly comprises a fourth steel alloy comprising: 0.02 % C, 1.31 % Mn, 0.02 % P, 0.001 % S, 0.45 % Si, 9.1 % Ni, and 18.7 % Cr. In an exemplary embodiment, the anisotropy of the predetermined portion of the assembly, prior to the radial expansion and plastic deformation, is about 1.34. In an exemplary embodiment, the yield point of the predetermined portion of the assembly is at most about 46.9 ksi prior to the radial expansion and plastic deformation; and wherein the yield point of the predetermined portion of the assembly is at least about 65.9 ksi after the radial expansion and plastic deformation. In an exemplary embodiment, the yield point of the predetermined portion of the assembly after the radial expansion and plastic deformation is at least about 40 % greater than the yield point of the predetermined portion of the assembly prior to the radial expansion and plastic deformation. In an exemplary embodiment, the anisotropy of the

predetermined portion of the assembly, prior to the radial expansion and plastic deformation, is at least about 1.48. In an exemplary embodiment, the yield point of the predetermined portion of the assembly is at most about 57.8 ksi prior to the radial expansion and plastic deformation; and wherein the yield point of the predetermined portion of the assembly is at least about 74.4 ksi after the radial expansion and plastic deformation. In an exemplary embodiment, the yield point of the predetermined portion of the assembly after the radial expansion and plastic deformation is at least about 28 % greater than the yield point of the predetermined portion of the assembly prior to the radial expansion and plastic deformation. In an exemplary embodiment, the anisotropy of the predetermined portion of the assembly, prior to the radial expansion and plastic deformation, is at least about 1.04. In an exemplary embodiment, the anisotropy of the predetermined portion of the assembly, prior to the radial expansion and plastic deformation, is at least about 1.92. In an exemplary embodiment, the anisotropy of the predetermined portion of the assembly, prior to the radial expansion and plastic deformation, is at least about 1.34. In an exemplary embodiment, the anisotropy of the predetermined portion of the assembly, prior to the radial expansion and plastic deformation, ranges from about 1.04 to about 1.92. In an exemplary embodiment, the yield point of the predetermined portion of the assembly, prior to the radial expansion and plastic deformation, ranges from about 47.6 ksi to about 61.7 ksi. In an exemplary embodiment, the expandability coefficient of the predetermined portion of the assembly, prior to the radial expansion and plastic deformation, is greater than 0.12. In an exemplary embodiment, the expandability coefficient of the predetermined portion of the assembly is greater than the expandability coefficient of the other portion of the assembly. In an exemplary embodiment, the assembly comprises a wellbore casing. In an exemplary embodiment, the assembly comprises a pipeline. In an exemplary embodiment, the assembly comprises a structural support. In an exemplary embodiment, the annulus is at least partially defined by an irregular surface. In an exemplary embodiment, the annulus is at least partially defined by a toothed surface. In an exemplary embodiment, the sealing element comprises an elastomeric material. In an exemplary embodiment, the sealing element comprises a metallic material. In an exemplary embodiment, the sealing element comprises an elastomeric and a metallic material.

[00622] A method of joining radially expandable tubular members is provided that includes providing a first tubular member; providing a second tubular member; providing a sleeve; mounting the sleeve for overlapping and coupling the first and second tubular members; threadably coupling the first and second tubular members at a first location; threadably coupling the first and second tubular members at a second location spaced apart from the first location; sealing an interface between the first and second tubular members between the first and second locations using a compressible sealing element, wherein the

first tubular member, second tubular member, sleeve, and the sealing element define a tubular assembly; and radially expanding and plastically deforming the tubular assembly; wherein, prior to the radial expansion and plastic deformation, a predetermined portion of the tubular assembly has a lower yield point than another portion of the tubular assembly. In an exemplary embodiment, the sealing element includes an irregular surface. In an exemplary embodiment, the sealing element includes a toothed surface. In an exemplary embodiment, the sealing element comprises an elastomeric material. In an exemplary embodiment, the sealing element comprises a metallic material. In an exemplary embodiment, the sealing element comprises an elastomeric and a metallic material. In an exemplary embodiment, the predetermined portion of the tubular assembly has a higher ductility and a lower yield point prior to the radial expansion and plastic deformation than after the radial expansion and plastic deformation. In an exemplary embodiment, the predetermined portion of the tubular assembly has a higher ductility prior to the radial expansion and plastic deformation than after the radial expansion and plastic deformation. In an exemplary embodiment, the predetermined portion of the tubular assembly has a lower yield point prior to the radial expansion and plastic deformation than after the radial expansion and plastic deformation. In an exemplary embodiment, the predetermined portion of the tubular assembly has a larger inside diameter after the radial expansion and plastic deformation than the other portion of the tubular assembly. In an exemplary embodiment, the method further includes: positioning another tubular assembly within the preexisting structure in overlapping relation to the tubular assembly; and radially expanding and plastically deforming the other tubular assembly within the preexisting structure; wherein, prior to the radial expansion and plastic deformation of the tubular assembly, a predetermined portion of the other tubular assembly has a lower yield point than another portion of the other tubular assembly. In an exemplary embodiment, the inside diameter of the radially expanded and plastically deformed other portion of the tubular assembly is equal to the inside diameter of the radially expanded and plastically deformed other portion of the other tubular assembly. In an exemplary embodiment, the predetermined portion of the tubular assembly comprises an end portion of the tubular assembly. In an exemplary embodiment, the predetermined portion of the tubular assembly comprises a plurality of predetermined portions of the tubular assembly. In an exemplary embodiment, the predetermined portion of the tubular assembly comprises a plurality of spaced apart predetermined portions of the tubular assembly. In an exemplary embodiment, the other portion of the tubular assembly comprises an end portion of the tubular assembly. In an exemplary embodiment, the other portion of the tubular assembly comprises a plurality of other portions of the tubular assembly. In an exemplary embodiment, the other portion of the tubular assembly comprises a plurality of spaced apart other portions of the tubular assembly. In an exemplary embodiment, the tubular assembly

comprises a plurality of tubular members coupled to one another by corresponding tubular couplings. In an exemplary embodiment, the tubular couplings comprise the predetermined portions of the tubular assembly; and wherein the tubular members comprise the other portion of the tubular assembly. In an exemplary embodiment, one or more of the tubular couplings comprise the predetermined portions of the tubular assembly. In an exemplary embodiment, one or more of the tubular members comprise the predetermined portions of the tubular assembly. In an exemplary embodiment, the predetermined portion of the tubular assembly defines one or more openings. In an exemplary embodiment, one or more of the openings comprise slots. In an exemplary embodiment, the anisotropy for the predetermined portion of the tubular assembly is greater than 1. In an exemplary embodiment, the anisotropy for the predetermined portion of the tubular assembly is greater than 1. In an exemplary embodiment, the strain hardening exponent for the predetermined portion of the tubular assembly is greater than 0.12. In an exemplary embodiment, the anisotropy for the predetermined portion of the tubular assembly is greater than 1; and wherein the strain hardening exponent for the predetermined portion of the tubular assembly is greater than 0.12. In an exemplary embodiment, the predetermined portion of the tubular assembly comprises a first steel alloy comprising: 0.065 % C, 1.44 % Mn, 0.01 % P, 0.002 % S, 0.24 % Si, 0.01 % Cu, 0.01 % Ni, and 0.02 % Cr. In an exemplary embodiment, the yield point of the predetermined portion of the tubular assembly is at most about 46.9 ksi prior to the radial expansion and plastic deformation; and wherein the yield point of the predetermined portion of the tubular assembly is at least about 65.9 ksi after the radial expansion and plastic deformation. In an exemplary embodiment, the yield point of the predetermined portion of the tubular assembly after the radial expansion and plastic deformation is at least about 40 % greater than the yield point of the predetermined portion of the tubular assembly prior to the radial expansion and plastic deformation. In an exemplary embodiment, the anisotropy of the predetermined portion of the tubular assembly, prior to the radial expansion and plastic deformation, is about 1.48. In an exemplary embodiment, the predetermined portion of the tubular assembly comprises a second steel alloy comprising: 0.18 % C, 1.28 % Mn, 0.017 % P, 0.004 % S, 0.29 % Si, 0.01 % Cu, 0.01 % Ni, and 0.03 % Cr. In an exemplary embodiment, the yield point of the predetermined portion of the tubular assembly is at most about 57.8 ksi prior to the radial expansion and plastic deformation; and wherein the yield point of the predetermined portion of the tubular assembly is at least about 74.4 ksi after the radial expansion and plastic deformation. In an exemplary embodiment, the yield point of the predetermined portion of the tubular assembly after the radial expansion and plastic deformation is at least about 28 % greater than the yield point of the predetermined portion of the tubular assembly prior to the radial expansion and plastic deformation. In an exemplary embodiment, the anisotropy of the predetermined

portion of the tubular assembly, prior to the radial expansion and plastic deformation, is about 1.04. In an exemplary embodiment, the predetermined portion of the tubular assembly comprises a third steel alloy comprising: 0.08 % C, 0.82 % Mn, 0.006 % P, 0.003 % S, 0.30 % Si, 0.16 % Cu, 0.05 % Ni, and 0.05 % Cr. In an exemplary embodiment, the anisotropy of the predetermined portion of the tubular assembly, prior to the radial expansion and plastic deformation, is about 1.92. In an exemplary embodiment, the predetermined portion of the tubular assembly comprises a fourth steel alloy comprising: 0.02 % C, 1.31 % Mn, 0.02 % P, 0.001 % S, 0.45 % Si, 9.1 % Ni, and 18.7 % Cr. In an exemplary embodiment, the anisotropy of the predetermined portion of the tubular assembly, prior to the radial expansion and plastic deformation, is about 1.34. In an exemplary embodiment, the yield point of the predetermined portion of the tubular assembly is at most about 46.9 ksi prior to the radial expansion and plastic deformation; and wherein the yield point of the predetermined portion of the tubular assembly is at least about 65.9 ksi after the radial expansion and plastic deformation. In an exemplary embodiment, the yield point of the predetermined portion of the tubular assembly after the radial expansion and plastic deformation is at least about 40 % greater than the yield point of the predetermined portion of the tubular assembly prior to the radial expansion and plastic deformation. In an exemplary embodiment, the anisotropy of the predetermined portion of the tubular assembly, prior to the radial expansion and plastic deformation, is at least about 1.48. In an exemplary embodiment, the yield point of the predetermined portion of the tubular assembly is at most about 57.8 ksi prior to the radial expansion and plastic deformation; and wherein the yield point of the predetermined portion of the tubular assembly is at least about 74.4 ksi after the radial expansion and plastic deformation. In an exemplary embodiment, the yield point of the predetermined portion of the tubular assembly after the radial expansion and plastic deformation is at least about 28 % greater than the yield point of the predetermined portion of the tubular assembly prior to the radial expansion and plastic deformation. In an exemplary embodiment, the anisotropy of the predetermined portion of the tubular assembly, prior to the radial expansion and plastic deformation, is at least about 1.04. In an exemplary embodiment, the anisotropy of the predetermined portion of the tubular assembly, prior to the radial expansion and plastic deformation, is at least about 1.92. In an exemplary embodiment, the anisotropy of the predetermined portion of the tubular assembly, prior to the radial expansion and plastic deformation, is at least about 1.34. In an exemplary embodiment, the anisotropy of the predetermined portion of the tubular assembly, prior to the radial expansion and plastic deformation, ranges from about 1.04 to about 1.92. In an exemplary embodiment, the yield point of the predetermined portion of the tubular assembly, prior to the radial expansion and plastic deformation, ranges from about 47.6 ksi to about 61.7 ksi. In an exemplary embodiment, the expandability coefficient of the predetermined

portion of the tubular assembly, prior to the radial expansion and plastic deformation, is greater than 0.12. In an exemplary embodiment, the expandability coefficient of the predetermined portion of the tubular assembly is greater than the expandability coefficient of the other portion of the tubular assembly. In an exemplary embodiment, the tubular assembly comprises a wellbore casing. In an exemplary embodiment, the tubular assembly comprises a pipeline. In an exemplary embodiment, the tubular assembly comprises a structural support. In an exemplary embodiment, the sleeve comprises: a plurality of spaced apart tubular sleeves coupled to and receiving end portions of the first and second tubular members. In an exemplary embodiment, the first tubular member comprises a first threaded connection; wherein the second tubular member comprises a second threaded connection; wherein the first and second threaded connections are coupled to one another; wherein at least one of the tubular sleeves is positioned in opposing relation to the first threaded connection; and wherein at least one of the tubular sleeves is positioned in opposing relation to the second threaded connection. In an exemplary embodiment, the first tubular member comprises a first threaded connection; wherein the second tubular member comprises a second threaded connection; wherein the first and second threaded connections are coupled to one another; and wherein at least one of the tubular sleeves is not positioned in opposing relation to the first and second threaded connections. In an exemplary embodiment, the carbon content of the tubular member is less than or equal to 0.12 percent; and wherein the carbon equivalent value for the tubular member is less than 0.21. In an exemplary embodiment, the tubular member comprises a wellbore casing.

[00623] An expandable tubular member has been described, wherein the carbon content of the tubular member is greater than 0.12 percent; and wherein the carbon equivalent value for the tubular member is less than 0.36. In an exemplary embodiment, the tubular member comprises a wellbore casing.

[00624] A method of selecting tubular members for radial expansion and plastic deformation has been described that includes: selecting a tubular member from a collection of tubular member; determining a carbon content of the selected tubular member; determining a carbon equivalent value for the selected tubular member; and if the carbon content of the selected tubular member is less than or equal to 0.12 percent and the carbon equivalent value for the selected tubular member is less than 0.21, then determining that the selected tubular member is suitable for radial expansion and plastic deformation.

[00625] A method of selecting tubular members for radial expansion and plastic deformation has been described that includes: selecting a tubular member from a collection of tubular member; determining a carbon content of the selected tubular member; determining a carbon equivalent value for the selected tubular member; and if the carbon content of the selected tubular member is greater than 0.12 percent and the carbon

equivalent value for the selected tubular member is less than 0.36, then determining that the selected tubular member is suitable for radial expansion and plastic deformation.

[00626] An expandable tubular member has been described that includes: a tubular body; wherein a yield point of an inner tubular portion of the tubular body is less than a yield point of an outer tubular portion of the tubular body. In an exemplary embodiment, the yield point of the inner tubular portion of the tubular body varies as a function of the radial position within the tubular body. In an exemplary embodiment, the yield point of the inner tubular portion of the tubular body varies in an linear fashion as a function of the radial position within the tubular body. In an exemplary embodiment, the yield point of the inner tubular portion of the tubular body varies in an non-linear fashion as a function of the radial position within the tubular body. In an exemplary embodiment, the yield point of the outer tubular portion of the tubular body varies as a function of the radial position within the tubular body. In an exemplary embodiment, the yield point of the outer tubular portion of the tubular body varies in an linear fashion as a function of the radial position within the tubular body. In an exemplary embodiment, the yield point of the outer tubular portion of the tubular body varies in an non-linear fashion as a function of the radial position within the tubular body. In an exemplary embodiment, the yield point of the inner tubular portion of the tubular body varies as a function of the radial position within the tubular body; and wherein the yield point of the outer tubular portion of the tubular body varies as a function of the radial position within the tubular body. In an exemplary embodiment, the yield point of the inner tubular portion of the tubular body varies in a linear fashion as a function of the radial position within the tubular body; and wherein the yield point of the outer tubular portion of the tubular body varies in a linear fashion as a function of the radial position within the tubular body. In an exemplary embodiment, the yield point of the inner tubular portion of the tubular body varies in a linear fashion as a function of the radial position within the tubular body; and wherein the yield point of the outer tubular portion of the tubular body varies in a non-linear fashion as a function of the radial position within the tubular body. In an exemplary embodiment, the yield point of the inner tubular portion of the tubular body varies in a non-linear fashion as a function of the radial position within the tubular body; and wherein the yield point of the outer tubular portion of the tubular body varies in a linear fashion as a function of the radial position within the tubular body. In an exemplary embodiment, the yield point of the inner tubular portion of the tubular body varies in a non-linear fashion as a function of the radial position within the tubular body; and wherein the yield point of the outer tubular portion of the tubular body varies in a non-linear fashion as a function of the radial position within the tubular body. In an exemplary embodiment, the rate of change of the yield point of the inner tubular portion of the tubular body is different than the rate of change of the yield point of the outer tubular portion of the tubular body. In an exemplary embodiment, the rate of change of

the yield point of the inner tubular portion of the tubular body is different than the rate of change of the yield point of the outer tubular portion of the tubular body.

[00627] A method of manufacturing an expandable tubular member has been described that includes: providing a tubular member; heat treating the tubular member; and quenching the tubular member; wherein following the quenching, the tubular member comprises a microstructure comprising a hard phase structure and a soft phase structure. In an exemplary embodiment, the provided tubular member comprises, by weight percentage, 0.065% C, 1.44% Mn, 0.01% P, 0.002% S, 0.24% Si, 0.01% Cu, 0.01% Ni, 0.02% Cr, 0.05% V, 0.01% Mo, 0.01% Nb, and 0.01%Ti. In an exemplary embodiment, the provided tubular member comprises, by weight percentage, 0.18% C, 1.28% Mn, 0.017% P, 0.004% S, 0.29% Si, 0.01% Cu, 0.01% Ni, 0.03% Cr, 0.04% V, 0.01% Mo, 0.03% Nb, and 0.01%Ti. In an exemplary embodiment, the provided tubular member comprises, by weight percentage, 0.08% C, 0.82% Mn, 0.006% P, 0.003% S, 0.30% Si, 0.06% Cu, 0.05% Ni, 0.05% Cr, 0.03% V, 0.03% Mo, 0.01% Nb, and 0.01%Ti. In an exemplary embodiment, the provided tubular member comprises a microstructure comprising one or more of the following: martensite, pearlite, vanadium carbide, nickel carbide, or titanium carbide. In an exemplary embodiment, the provided tubular member comprises a microstructure comprising one or more of the following: pearlite or pearlite striation. In an exemplary embodiment, the provided tubular member comprises a microstructure comprising one or more of the following: grain pearlite, widmanstatten martensite, vanadium carbide, nickel carbide, or titanium carbide. In an exemplary embodiment, the heat treating comprises heating the provided tubular member for about 10 minutes at 790 °C. In an exemplary embodiment, the quenching comprises quenching the heat treated tubular member in water. In an exemplary embodiment, following the quenching, the tubular member comprises a microstructure comprising one or more of the following: ferrite, grain pearlite, or martensite. In an exemplary embodiment, following the quenching, the tubular member comprises a microstructure comprising one or more of the following: ferrite, martensite, or bainite. In an exemplary embodiment, following the quenching, the tubular member comprises a microstructure comprising one or more of the following: bainite, pearlite, or ferrite. In an exemplary embodiment, following the quenching, the tubular member comprises a yield strength of about 67ksi and a tensile strength of about 95 ksi. In an exemplary embodiment, following the quenching, the tubular member comprises a yield strength of about 82 ksi and a tensile strength of about 130 ksi. In an exemplary embodiment, following the quenching, the tubular member comprises a yield strength of about 60 ksi and a tensile strength of about 97 ksi. In an exemplary embodiment, the method further includes: positioning the quenched tubular member within a preexisting structure; and radially expanding and plastically deforming the tubular member within the preexisting structure.

[00628] A system for radially expanding and plastically deforming a tubular member has been described that includes an expansion device positioned in the tubular member, wherein the coefficient of friction between the expansion device and the tubular member during radial expansion and plastic deformation is less than 0.08. In an exemplary embodiment, the coefficient of friction is in the range of .02 to 0.05. In an exemplary embodiment, the system includes a lubricant between the tubular member and the expansion device. In an exemplary embodiment, the lubricant includes oil based lubricants, H1 oil, H2 oil, H3 oil, H4 oil, H5 oil, H6 oil, H7 oil, grease, water based lubricants, drilling mud, drilling mud and solid lubricants, grease combined with a solid lubricant, at least 10% Graphite, or at least 10% Molybdenum Disulfide. In an exemplary embodiment, the system includes a coating on the expansion device. In an exemplary embodiment, the coating may be Phygen film. In an exemplary embodiment, the system includes a coating on the tubular member. In an exemplary embodiment, the coating on the tubular member includes PTFE, PTFE based or graphite based. In an exemplary embodiment, the expansion device includes DC53 material, DC2 material, DC3 material, DC5 material, DC7 material, M2 material, CPM M4 material, 10V material, 3V material. In an exemplary embodiment, the expansion device includes an REM finish, a processed finish, or a relatively smooth surface roughness. In an exemplary embodiment, the expansion device includes a relatively smooth surface roughness and includes relatively evenly space oil pockets. In an exemplary embodiment, the expansion device includes a smooth surface roughness in the range of 0.02 to 0.1 micrometers In an exemplary embodiment, the lubricant is injected through at least a portion of the expansion device between the tubular member and the expansion device. In an exemplary embodiment, the lubricant is injected through at least a portion of the expansion device between the tubular member and the expansion device when a predetermined pressure is met. In an exemplary embodiment, the lubricant is injected through at least two portions of the expansion device between the tubular member and the expansion device at two different pressures. In an exemplary embodiment, the expansion device includes a tapered portion with an outer surface, internal flow passage in the tapered portion and at least one circumferential groove having a first edge and a second edge having with a sliding angle on the outer surface of the tapered portion fluidicly coupled to the internal flow passage for receiving lubricant during radial expansion and plastic deformation of the tubular member, wherein the sliding angle is less than or equal to 30 degrees. In an exemplary embodiment, the expansion device includes a tapered portion with an outer surface, internal flow passage in the tapered portion, and at least one circumferential groove having a first edge and a second edge having with a sliding angle on the outer surface of the tapered portion fluidicly coupled to the internal flow passage for receiving lubricant during radial expansion and plastic deformation of the tubular member, wherein the sliding angle is less

than or equal to 10 degrees. In an exemplary embodiment, the system includes a lubricant between the tubular member and the expansion device, comprising at least nine components selected from the group consisting of: a base oil; metal deactivator; antioxidants; sulfurized natural oils; phosphate ester; phosphoric acid; viscosity modifier; pour-point depressant; defoamer; and carboxylic acid soaps. In an exemplary embodiment, the expansion device includes, a tapered portion having a tapered faceted polygonal outer expansion surface. In an exemplary embodiment, the tubular member has a non-uniform wall thickness and the expansion device includes a tapered portion having a tapered faceted polygonal outer expansion surface. In an exemplary embodiment, the lubricant is stored in a reservoir with electrodes that are electrically coupled a capacitor in the expansion device and is injected through at least a portion of the expansion device between the tubular member and the expansion device when the capacitors discharges. In an exemplary embodiment, the expansion device includes a wellbore casing, a pipeline, or a structural support. In an exemplary embodiment, the expansion device includes expansion cone.

[00629] A method of radially expanding and plastically deforming a tubular member has been described that includes positioning an expansion device having a first tapered end and a second end at least partially within the tubular member, displacing the expansion device relative to the tubular member to radially expand and plastically deform the tubular member, and wherein the coefficient of friction between the expansion device and the tubular member during radial expansion and plastic deformation is less than 0.08. In an exemplary embodiment, the coefficient of friction is in the range of .02 to 0.05. In an exemplary embodiment, the method includes injecting lubricant between the tubular member and the expansion device. In an exemplary embodiment, the lubricant includes oil based lubricants, H1 oil, H2 oil, H3 oil, H4 oil, H5 oil, H6 oil, H7 oil, grease, water based lubricants, drilling mud, drilling mud and solid lubricants, grease combined with a solid lubricant, at least 10% Graphite, or at least 10% Molybdenum Disulfide. In an exemplary embodiment, the method includes applying a coating on the expansion device prior to positioning within the tubular member. In an exemplary embodiment, the coating may be Phygen film. In an exemplary embodiment, the method includes applying a coating on the tubular member prior to positioning the expansion device within the tubular member. In an exemplary embodiment, the coating on the tubular member includes PTFE, PTFE based or graphite based. In an exemplary embodiment, the expansion device includes DC53 material, DC2 material, DC3 material, DC5 material, DC7 material, M2 material, CPM M4 material, 10V material, 3V material. In an exemplary embodiment, the expansion device includes an REM finish, a processed finish, or a relatively smooth surface roughness. In an exemplary embodiment, the expansion device includes a relatively smooth surface roughness and includes relatively evenly space oil pockets. In an exemplary embodiment, the expansion

device includes a smooth surface roughness in the range of 0.02 to 0.1 micrometers In an exemplary embodiment, the method includes injecting lubricant through at least a portion of the expansion device between the tubular member and the expansion device. In an exemplary embodiment, the method includes injecting lubricant through at least a portion of the expansion device between the tubular member and the expansion device when a predetermined pressure is met. In an exemplary embodiment, the method includes injecting lubricant through at least two portions of the expansion device between the tubular member and the expansion device at two different pressures. In an exemplary embodiment, the expansion device includes a tapered portion with an outer surface, internal flow passage in the tapered portion and at least one circumferential groove having a first edge and a second edge having with a sliding angle on the outer surface of the tapered portion fluidicly coupled to the internal flow passage for receiving lubricant during radial expansion and plastic deformation of the tubular member, wherein the sliding angle is less than or equal to 30 degrees. In an exemplary embodiment, the expansion device includes a tapered portion with an outer surface, internal flow passage in the tapered portion, and at least one circumferential groove having a first edge and a second edge having with a sliding angle on the outer surface of the tapered portion fluidicly coupled to the internal flow passage for receiving lubricant during radial expansion and plastic deformation of the tubular member, wherein the sliding angle is less than or equal to 10 degrees. In an exemplary embodiment, the method includes injecting lubricant between the tubular member and the expansion device, comprising at least nine components selected from the group consisting of: a base oil; metal deactivator; antioxidants; sulfurized natural oils; phosphate ester; phosphoric acid; viscosity modifier; pour-point depressant; defoamer; and carboxylic acid soaps. In an exemplary embodiment, the expansion device includes a tapered portion having a tapered faceted polygonal outer expansion surface. In an exemplary embodiment, the expansion device includes, a tapered portion having a tapered faceted polygonal outer expansion surface. In an exemplary embodiment, the tubular member has a non-uniform wall thickness and the expansion device includes a tapered portion having a tapered faceted polygonal outer expansion surface. In an exemplary embodiment, the lubricant is stored in a reservoir with electrodes that are electrically coupled a capacitor in the expansion device and is injected through at least a portion of the expansion device between the tubular member and the expansion device when the capacitors discharges. In an exemplary embodiment, the expansion device includes a wellbore casing, a pipeline, or a structural support. In an exemplary embodiment, the expansion device includes expansion cone.

[00630] A system for radially expanding and plastically deforming a tubular member has been described that includes means for positioning an expansion device having a first tapered end and a second end at least partially within the tubular member and means for

displacing the expansion device relative to the tubular member to radially expand and plastically deform the tubular member, wherein the coefficient of friction between the expansion device and the tubular member during radial expansion and plastic deformation is less than 0.08. In an exemplary embodiment, the coefficient of friction is in the range of .02 to 0.05. In an exemplary embodiment, the system, includes a means for injecting lubricant between the tubular member and the expansion device. In an exemplary embodiment, the lubricant includes oil based lubricants, H1 oil, H2 oil, H3 oil, H4 oil, H5 oil, H6 oil, H7 oil, grease, water based lubricants, drilling mud, drilling mud and solid lubricants, grease combined with a solid lubricant, at least 10% Graphite, or at least 10% Molybdenum Disulfide. In an exemplary embodiment, the system includes a means for applying a coating on the expansion device prior to positioning within the tubular member. In an exemplary embodiment, the coating may be Phygen film. In an exemplary embodiment, the method includes applying a coating on the tubular member prior to positioning the expansion device within the tubular member. In an exemplary embodiment, the coating on the tubular member includes PTFE, PTFE based or graphite based. In an exemplary embodiment, the expansion device includes DC53 material, DC2 material, DC3 material, DC5 material, DC7 material, M2 material, CPM M4 material, 10V material, 3V material. In an exemplary embodiment, the expansion device includes an REM finish, a processed finish, or a relatively smooth surface roughness. In an exemplary embodiment, the expansion device includes a relatively smooth surface roughness and includes relatively evenly space oil pockets. In an exemplary embodiment, the expansion device includes a smooth surface roughness in the range of 0.02 to 0.1 micrometers In an exemplary embodiment, the system includes a means for injecting lubricant through at least a portion of the expansion device between the tubular member and the expansion device. In an exemplary embodiment, the system includes a means for injecting lubricant through at least a portion of the expansion device between the tubular member and the expansion device when a predetermined pressure is met. In an exemplary embodiment, the system includes a means for injecting lubricant through at least two portions of the expansion device between the tubular member and the expansion device at two different pressures. In an exemplary embodiment, the expansion device includes a tapered portion with an outer surface, internal flow passage in the tapered portion and at least one circumferential groove having a first edge and a second edge having with a sliding angle on the outer surface of the tapered portion fluidicly coupled to the internal flow passage for receiving lubricant during radial expansion and plastic deformation of the tubular member, wherein the sliding angle is less than or equal to 30 degrees. In an exemplary embodiment, the expansion device includes a tapered portion with an outer surface, internal flow passage in the tapered portion, and at least one circumferential groove having a first edge and a second edge having with a sliding angle on the outer surface of the

tapered portion fluidicly coupled to the internal flow passage for receiving lubricant during radial expansion and plastic deformation of the tubular member, wherein the sliding angle is less than or equal to 10 degrees. In an exemplary embodiment, the system includes a means for injecting lubricant between the tubular member and the expansion device, comprising at least nine components selected from the group consisting of: a base oil; metal deactivator; antioxidants; sulfurized natural oils; phosphate ester; phosphoric acid; viscosity modifier; pour-point depressant; defoamer; and carboxylic acid soaps. In an exemplary embodiment, the expansion device includes a tapered portion having a tapered faceted polygonal outer expansion surface. In an exemplary embodiment, the expansion device includes, a tapered portion having a tapered faceted polygonal outer expansion surface. In an exemplary embodiment, the tubular member has a non-uniform wall thickness and the expansion device includes a tapered portion having a tapered faceted polygonal outer expansion surface. In an exemplary embodiment, the lubricant is stored in a reservoir with electrodes that are electrically coupled a capacitor in the expansion device and is injected through at least a portion of the expansion device between the tubular member and the expansion device when the capacitors discharges. In an exemplary embodiment, the expansion device includes a wellbore casing, a pipeline, or a structural support. In an exemplary embodiment, the expansion device includes expansion cone.

[00631] A lubricant for injecting in an interface between a tubular member and an expansion device has been describe that includes at least eight components selected from the group consisting of: a base oil; metal deactivator; antioxidants; sulfurized natural oils; phosphate ester; phosphoric acid; viscosity modifier; pour-point depressant; defoamer; and carboxylic acid soaps. In an exemplary embodiment, the lubricant by weight includes: 64.25 – 90.89% base oil; 0.02 –0.05% metal deactivator; 0.5 – 3.0% antioxidants; 4 -12% sulfurized natural oils; 4 -12% phosphate ester; 0.4 – 1.5% phosphoric acid; 0.08 – 1.5% viscosity modifier; 0.1 – 0.5% pour-point depressant; 0.01 – 0.2% defoamer; and 0 – 5% carboxylic acid soaps.

[00632] A lubricant for injecting in an interface between a tubular member and an expansion device has been described that includes 77.81% canola oil; 0.04% tolyltriazole; 1.0% phenolic antioxidant; 10% sulfurized natural oil or sulferized lard oil; 9% phosphate ester; 1% phosphoric acid; 0.8% styrene hydrocarbon polymer; 0.3% alkyl ester copolymer; and 0.05% silicon based antifoam agent.

[00633] A lubricant for injecting in an interface between a tubular member and an expansion device has been described that includes: 64.25% canola oil; 0.05% tolyltriazole; 1.0% aminic antioxidant; 2.0% phenolic antioxidant, 12% sulfurized natural oil or sulferized lard oil; 12% phosphate ester; 1.5% phosphoric acid; 1.5% styrene hydrocarbon polymer; 0.5% alkyl ester copolymer; 0.2% silicon based antifoam agent., and 5% carbozylic acid

soap.

[00634] A lubricant for injecting in an interface between a tubular member and an expansion device has been described that includes: 90.89% canola oil; 0.02% tolyltriazole; 0.5% phenolic antioxidant; 4% sulfurized natural oil or sulferized lard oil; 4% phosphate ester; 0.4% phosphoric acid; 0.08% styrene hydrocarbon polymer; 0.1% alkyl ester copolymer; and 0.01% silicon based antifoam agent.

[00635] A lubricant for injecting in an interface between a tubular member and an expansion device has been described that includes: 68.71% canola oil; 0.04% tolyltriazole; 0.5% aminic antioxidant, 1.0% phenolic antioxidant; 12% sulfurized natural oil or sulferized lard oil; 10% phosphate ester; 1.1% phosphoric acid; 1.5% styrene hydrocarbon polymer; 0.1% alkyl ester copolymer; 0.05% silicon based antifoam agent., and 5% carbozylic acid soap.

[00636] A lubricant for injecting in an interface between a tubular member and an expansion device has been described that includes: 82.07% canola oil; 0.03% tolyltriazole; 0.5% aminic antioxidant, 0.5% phenolic antioxidant; 10% sulfurized natural oil or sulferized lard oil; 5% phosphate ester; 0.5% phosphoric acid; 0.1% styrene hydrocarbon polymer; 0.2% alkyl ester copolymer; 0.1% silicon based antifoam agent., and 1% carbozylic acid soap.

[00637] A lubricant for injecting in an interface between a tubular member and an expansion device has been described that includes: 80.68% canola oil; 0.04% tolyltriazole; 1% phenolic antioxidant; 8% sulfurized natural oil or sulferized lard oil; 9% phosphate ester; 1% phosphoric acid; 0.1% styrene hydrocarbon polymer; 0.1% alkyl ester copolymer; and 0.08% silicon based antifoam agent.

[00638] A lubricant for injecting in an interface between a tubular member and an expansion device has been described that includes: 80.31% canola oil; 0.04% tolyltriazole; 1.1% phenolic antioxidant; 9% sulfurized natural oil or sulferized lard oil; 8% phosphate ester; 0.8% phosphoric acid; 0.4% styrene hydrocarbon polymer; 0.3% alkyl ester copolymer; and 0.05% silicon based antifoam agent.

[00639] A lubricant for injecting in an interface between a tubular member and an expansion device has been described that includes: at least 10% Graphite.

[00640] A lubricant for injecting in an interface between a tubular member and an expansion device has been described that includes: at least 10% Molybedenum Disulfide in a thickener in with a dropping point above 350-400F.

[00641] An expansion device for radially expanding and plastically deforming the tubular member has been described that includes one or more expansion surfaces on the expansion device for engaging the interior surface of the tubular member during the radial expansion and plastic deformation of the tubular member; and a lubrication device operably

coupled to the expansion surface for injecting lubricant into an interface between the expansion surface and the tubular member during the radial expansion and plastic deformation of the tubular member when a predetermined pressure for lubrication is reached. In an exemplary embodiment, the lubrication device includes a pump. In an exemplary embodiment, the lubrication device includes a reservoir operably coupled to the expansion surface for house a lubricant; a means for pressurizing the lubricant; and a means for injecting the lubricant in the reservoir into the interface when the predetermine pressure is reached. In an exemplary embodiment, the lubrication device includes a reservoir operably coupled to the expansion surface for house a lubricant; a means for pressurizing the lubricant, and a valve fluidicly coupled to the reservoir and the expansion surface for injecting the lubricant into the interface when the predetermine pressure is reached. In an exemplary embodiment, the lubrication device includes a reservoir operably coupled to the expansion surface for house a lubricant, a means for pressurizing the lubricant, a pressure enhancer operably coupled to the reservoir to increase the pressure on the lubricant in the reservoir, and a valve fluidicly coupled to the reservoir and the expansion surface for injecting the lubricant into the interface when the predetermine pressure is reached. In an exemplary embodiment, the lubrication device includes a reservoir operably coupled to the expansion surface for house a lubricant, a means for pressurizing the lubricant, a piston operably coupled to the reservoir, and a valve fluidicly coupled to the reservoir and the expansion surface for injecting the lubricant into the interface when the predetermine pressure is reached. In an exemplary embodiment, the coefficient of friction between the expansion device and the tubular member during radial expansion and plastic deformation is less than 0.08. In an exemplary embodiment, the lubrication device includes the coefficient of friction between the expansion device and the tubular member during radial expansion and plastic deformation is in the range of .02 to 0.05. In an exemplary embodiment, the lubricant includes oil based lubricants, H1 oil, H2 oil, H3 oil, H4 oil, H5 oil, H6 oil, H7 oil, grease, water based lubricants, drilling mud, drilling mud and solid lubricants, grease combined with a solid lubricant, at least 10% Graphite, or at least 10% Molybdenum Disulfide. In an exemplary embodiment, the expansion device includes a coating on the expansion device. In an exemplary embodiment, the coating may be Phygen film. In an exemplary embodiment, the expansion device includes a coating on the tubular member. In an exemplary embodiment, the coating on the tubular member includes PTFE, PTFE based or graphite based. In an exemplary embodiment, the expansion device includes DC53 material, DC2 material, DC3 material, DC5 material, DC7 material, M2 material, CPM M4 material, 10V material, 3V material. In an exemplary embodiment, the expansion device includes an REM finish, a processed finish, or a relatively smooth surface roughness. In an exemplary embodiment, the expansion device includes a relatively smooth surface

roughness and includes relatively evenly space oil pockets. In an exemplary embodiment, the expansion device includes a smooth surface roughness in the range of 0.02 to 0.1 micrometers In an exemplary embodiment, the lubricant is injected through at least a portion of the expansion device between the tubular member and the expansion device. In an exemplary embodiment, the expansion device includes a means for injecting lubricant through at least a portion of the expansion device between the tubular member and the expansion device when a predetermined pressure is met. In an exemplary embodiment, the expansion device includes a means for injecting lubricant through at least two portions of the expansion device between the tubular member and the expansion device at two different pressures. In an exemplary embodiment, the expansion device includes a tapered portion with an outer surface, internal flow passage in the tapered portion and at least one circumferential groove having a first edge and a second edge having with a sliding angle on the outer surface of the tapered portion fluidicly coupled to the internal flow passage for receiving lubricant during radial expansion and plastic deformation of the tubular member, wherein the sliding angle is less than or equal to 30 degrees. In an exemplary embodiment, the expansion device includes a tapered portion with an outer surface, internal flow passage in the tapered portion, and at least one circumferential groove having a first edge and a second edge having with a sliding angle on the outer surface of the tapered portion fluidicly coupled to the internal flow passage for receiving lubricant during radial expansion and plastic deformation of the tubular member, wherein the sliding angle is less than or equal to 10 degrees. In an exemplary embodiment, the expansion device includes a lubricant between the tubular member and the expansion device, comprising at least nine components selected from the group consisting of: a base oil; metal deactivator; antioxidants; sulfurized natural oils; phosphate ester; phosphoric acid; viscosity modifier; pour-point depressant; defoamer; and carboxylic acid soaps. In an exemplary embodiment, the expansion device includes, a tapered portion having a tapered faceted polygonal outer expansion surface. In an exemplary embodiment, the tubular member has a non-uniform wall thickness and the expansion device includes a tapered portion having a tapered faceted polygonal outer expansion surface. In an exemplary embodiment, the lubricant is stored in a reservoir with electrodes that are electrically coupled a capacitor in the expansion device and is injected through at least a portion of the expansion device between the tubular member and the expansion device when the capacitors discharges. In an exemplary embodiment, the expansion device includes a wellbore casing, a pipeline, or a structural support. In an exemplary embodiment, the expansion device includes expansion cone.

[00642] A method for radially expanding and plastically deforming the tubular member has been described that includes positioning an expansion device having one or more expansion surfaces in the interior surface of the tubular member, displacing the expansion

device relative to the tubular member to radially expand and plastically deform the tubular member, and operating a lubrication device to inject lubricant into an interface between the expansion surface and the tubular member when a predetermined lubricant pressure is reached. In an exemplary embodiment, the lubrication device includes a pump. In an exemplary embodiment, the lubrication device includes a reservoir operably coupled to the expansion surface for house a lubricant; a means for pressurizing the lubricant; and a means for injecting the lubricant in the reservoir into the interface when the predetermine pressure is reached. In an exemplary embodiment, the lubrication device includes a reservoir operably coupled to the expansion surface for house a lubricant; a means for pressurizing the lubricant, and a valve fluidicly coupled to the reservoir and the expansion surface for injecting the lubricant into the interface when the predetermine pressure is reached. In an exemplary embodiment, the lubrication device includes a reservoir operably coupled to the expansion surface for house a lubricant, a means for pressurizing the lubricant, a pressure enhancer operably coupled to the reservoir to increase the pressure on the lubricant in the reservoir, and a valve fluidicly coupled to the reservoir and the expansion surface for injecting the lubricant into the interface when the predetermine pressure is reached. In an exemplary embodiment, the lubrication device includes a reservoir operably coupled to the expansion surface for house a lubricant, a means for pressurizing the lubricant, a piston operably coupled to the reservoir, and a valve fluidicly coupled to the reservoir and the expansion surface for injecting the lubricant into the interface when the predetermine pressure is reached. In an exemplary embodiment, the coefficient of friction between the expansion device and the tubular member during radial expansion and plastic deformation is less than 0.08. In an exemplary embodiment, the lubrication device includes the coefficient of friction between the expansion device and the tubular member during radial expansion and plastic deformation is in the range of .02 to 0.05. In an exemplary embodiment, the lubricant includes oil based lubricants, H1 oil, H2 oil, H3 oil, H4 oil, H5 oil, H6 oil, H7 oil, grease, water based lubricants, drilling mud, drilling mud and solid lubricants, grease combined with a solid lubricant, at least 10% Graphite, or at least 10% Molybdenum Disulfide. In an exemplary embodiment, the expansion device includes a coating on the expansion device. In an exemplary embodiment, the coating may be Phygen film. In an exemplary embodiment, the expansion device includes a coating on the tubular member. In an exemplary embodiment, the coating on the tubular member includes PTFE, PTFE based or graphite based. In an exemplary embodiment, the expansion device includes DC53 material, DC2 material, DC3 material, DC5 material, DC7 material, M2 material, CPM M4 material, 10V material, 3V material. In an exemplary embodiment, the expansion device includes an REM finish, a processed finish, or a relatively smooth surface roughness. In an exemplary embodiment, the expansion device includes a relatively smooth surface

roughness and includes relatively evenly space oil pockets. In an exemplary embodiment, the expansion device includes a smooth surface roughness in the range of 0.02 to 0.1 micrometers In an exemplary embodiment, the method includes injecting lubricant through at least two portions of the expansion device between the tubular member and the expansion device at two different pressures. In an exemplary embodiment, the expansion device includes a tapered portion with an outer surface, internal flow passage in the tapered portion, at least one circumferential groove having a first edge and a second edge having with a sliding angle on the outer surface of the tapered portion fluidicly coupled to the internal flow passage for receiving lubricant during radial expansion and plastic deformation of the tubular member, wherein the sliding angle is less than or equal to 30 degrees and the expansion surfaces are located on the tapered portion. In an exemplary embodiment, the expansion device includes a tapered portion with an outer surface, internal flow passage in the tapered portion, at least one circumferential groove having a first edge and a second edge having with a sliding angle on the outer surface of the tapered portion fluidicly coupled to the internal flow passage for receiving lubricant during radial expansion and plastic deformation of the tubular member, wherein the sliding angle is less than or equal to 10 degrees and the expansion surfaces are located on the tapered portion. In an exemplary embodiment, the lubricant includes at least nine components selected from the group consisting of: a base oil; metal deactivator; antioxidants; sulfurized natural oils; phosphate ester; phosphoric acid; viscosity modifier; pour-point depressant; defoamer; and carboxylic acid soaps. In an exemplary embodiment, the expansion device includes a tapered portion having a tapered faceted polygonal outer expansion surface. In an exemplary embodiment, the tubular member includes a tapered portion having a tapered faceted polygonal outer expansion surface. In an exemplary embodiment, the lubricant is stored in a reservoir with electrodes that are electrically coupled a capacitor in the expansion device and the method includes charging the capacitor, discharging the capacitor through the electrodes, and injecting the lubricant through at least a portion of the expansion device between the tubular member and the expansion device when the capacitors discharges. In an exemplary embodiment, the tubular member includes a wellbore casing, a pipeline or a structural support. In an exemplary embodiment, the expansion device includes an expansion cone.

[00643] A lubricant delivery assembly for radially expanding and plastically deforming a tubular member has been described that includes an expansion cone having a tapered portion with an outer surface, at least one reservoir for housing a lubricant, at least one circumferential groove on the outer surface fluidicly connected to the reservoir, and a lubricant injection mechanism to force lubricant into the at least one circumferential groove while radially expanding and plastically deforming the tubular member when a predetermined lubricant pressure is reached. In an exemplary embodiment, the lubricant

injection mechanism is a valve and the lubricant is drilling fluid received in the reservoir. In an exemplary embodiment, the reservoir is fluidicly connected to drilling fluid used to expand the tubular member and the lubricant injection mechanism includes a pressure accelerator received within the reservoir that separates the drilling fluid and the media.

[00644] An expansion device for radially expanding and plastically deforming a tubular member has been described that includes a tapered portion with an outer surface, internal flow passage in the tapered portion, and at least one circumferential groove having a first edge and a second edge with a predetermined sliding angle on the outer surface of the tapered portion fluidicly coupled to the internal flow passage for receiving lubricant during radial expansion and plastic deformation of the tubular member, wherein the sliding angle is less than or equal to 30 degrees.

[00645] An expansion cone for radially expanding and plastically deforming a tubular member has been described that includes a leading portion with an outer surface, internal flow passage in the leading portion, at least one circumferential groove on the outer surface of the tapered portion fluidicly coupled to the internal flow passage for receiving lubricant during radial expansion and plastic deformation of the tubular member; a tapered portion with an outer surface internal flow passage in the tapered portion and at least one circumferential groove on the outer surface of the tapered portion fluidicly coupled to the internal flow passage for receiving lubricant during radial expansion and plastic deformation of the tubular member.

[00646] An expansion cone for radially expanding and plastically deforming a tubular member has been described that includes a leading portion with an outer surface, internal flow passage in the leading portion, at least one circumferential groove on the outer surface of the tapered portion fluidicly coupled to the internal flow passage for receiving lubricant during radial expansion and plastic deformation of the tubular member, a tapered portion with an outer surface, internal flow passage in the tapered portion, and at least one circumferential groove on the outer surface of the tapered portion fluidicly coupled to the internal flow passage for receiving lubricant during radial expansion and plastic deformation of the tubular member, wherein the lubricant in the leading portion is at pressure different from the lubricant in the tapered portion.

[00647] An expansion cone for radially expanding and plastically deforming a tubular member has been described that includes a leading portion with an outer surface, internal flow passage in the leading portion, at least one circumferential groove on the outer surface of the tapered portion fluidicly coupled to the internal flow passage for receiving lubricant during radial expansion and plastic deformation of the tubular member, a tapered portion with an outer surface, internal flow passage in the tapered portion, and at least one circumferential groove having a first edge and a second edge with a second predetermined

sliding angle on the outer surface of the tapered portion fluidicly coupled to the internal flow passage for receiving lubricant during radial expansion and plastic deformation of the tubular member; wherein the second sliding angle is less than or equal to 30 degrees.

[00648] An expansion cone for radially expanding and plastically deforming a tubular member has been described that includes a leading portion with an outer surface, internal flow passage in the leading portion, at least one circumferential groove on the outer surface of the tapered portion fluidicly coupled to the internal flow passage for receiving lubricant during radial expansion and plastic deformation of the tubular member, a tapered portion with an outer surface, internal flow passage in the tapered portion, and at least one circumferential groove having a first edge and a second edge with a second predetermined sliding angle on the outer surface of the tapered portion fluidicly coupled to the internal flow passage for receiving lubricant during radial expansion and plastic deformation of the tubular member, wherein the second sliding angle is less than or equal to 30 degrees.

[00649] An expansion cone for radially expanding and plastically deforming a tubular member has been described that includes a leading portion with an outer surface, internal flow passage in the leading portion, at least one circumferential groove on the outer surface of the tapered portion fluidicly coupled to the internal flow passage for receiving lubricant during radial expansion and plastic deformation of the tubular member from the internal flow passage, a tapered portion with an outer surface, internal flow passage in the tapered portion, and at least one circumferential groove having a first edge and a second edge with a second predetermined sliding angle on the outer surface of the tapered portion fluidicly coupled to the internal flow passage for receiving lubricant during radial expansion and plastic deformation of the tubular member; wherein the second sliding angle is less than or equal to 30 degrees, wherein the lubricant in the leading portion is at pressure different from the lubricant in the tapered portion.

[00650] A method of reducing the coefficient of friction between the expansion device and the tubular member during radial expansion to less than 0.08 has been described that includes altering at least one of the elements selected from the group consisting of: expansion device geometry, expansion device composition, expansion device surface roughness, expansion device texture, expansion device coating, lubricant composition, lubricant environmental issues, lubricant frictional modifiers, tubular member roughness, and tubular member coating.

[00651] A method of reducing the coefficient of friction between the expansion device and the tubular member during radial expansion to less than or equal to 0.05 has been describe that includes altering at least one of the elements selected from the group consisting of: expansion device geometry, expansion device composition, expansion device surface roughness, expansion device texture, expansion device coating, lubricant

composition, lubricant environmental issues, lubricant frictional modifiers, tubular member roughness, and tubular member coating.

[00652] A method of reducing the coefficient of friction between the expansion device and the tubular member during radial expansion to less than or equal to 0.02 has been describe that includes altering at least one of the elements selected from the group consisting of: expansion device geometry, expansion device composition, expansion device surface roughness, expansion device texture, expansion device coating, lubricant composition, lubricant environmental issues, lubricant frictional modifiers, tubular member roughness, and tubular member coating.

[00653] A lubrication system for lubricating an interface between a first element and a second element has been described that includes a vaporizer proximate to the interface for vaporizing a lubricant to inject the lubricant in the interface. In an exemplary embodiment, the first element includes an expansion device and the second element includes tubular member during radial expansion and plastic deformation of the tubular member. In an exemplary embodiment, the vaporizer includes a reservoir for housing a lubricant, and an electric pulse generator to create an electric pulse in the lubricant. In an exemplary embodiment, the electric impulse generator includes at least two electrodes housed in the reservoir and at least one capacitor electrically coupled to the electrode. In an exemplary embodiment, the vaporizer includes a reservoir for housing a lubricant and an magnetic pulse generator to create a magnetic pulse in the lubricant. In an exemplary embodiment, the electric impulse generator includes magnetic coil housed in the reservoir. In an exemplary embodiment, the system includes an expansion device for positioning in a tubular member and wherein the coefficient of friction between the expansion device and the tubular member during radial expansion and plastic deformation is less than 0.08. In an exemplary embodiment, the coefficient of friction is in the range of .02 to 0.05. In an exemplary embodiment, the system includes a lubricant between the tubular member and the expansion device. In an exemplary embodiment, the lubricant includes oil based lubricants, H1 oil, H2 oil, H3 oil, H4 oil, H5 oil, H6 oil, H7 oil, grease, water based lubricants, drilling mud, drilling mud and solid lubricants, grease combined with a solid lubricant, at least 10% Graphite, or at least 10% Molybdenum Disulfide. In an exemplary embodiment, the system includes a coating on the expansion device. In an exemplary embodiment, the coating may be Phygen film. In an exemplary embodiment, the system includes a coating on the tubular member. In an exemplary embodiment, the coating on the tubular member includes PTFE, PTFE based or graphite based. In an exemplary embodiment, the expansion device includes DC53 material, DC2 material, DC3 material, DC5 material, DC7 material, M2 material, CPM M4 material, 10V material, 3V material. In an exemplary embodiment, the expansion device includes an REM finish, a processed finish, or a relatively smooth surface roughness. In an

exemplary embodiment, the expansion device includes a relatively smooth surface roughness and includes relatively evenly space oil pockets. In an exemplary embodiment, the expansion device includes a smooth surface roughness in the range of 0.02 to 0.1 micrometers In an exemplary embodiment, the lubricant is injected through at least a portion of the expansion device between the tubular member and the expansion device. In an exemplary embodiment, the lubricant is injected through at least a portion of the expansion device between the tubular member and the expansion device when a predetermined pressure is met. In an exemplary embodiment, the lubricant is injected through at least two portions of the expansion device between the tubular member and the expansion device at two different pressures. In an exemplary embodiment, the expansion device includes a tapered portion with an outer surface, internal flow passage in the tapered portion and at least one circumferential groove having a first edge and a second edge having with a sliding angle on the outer surface of the tapered portion fluidicly coupled to the internal flow passage for receiving lubricant during radial expansion and plastic deformation of the tubular member, wherein the sliding angle is less than or equal to 30 degrees. In an exemplary embodiment, the expansion device includes a tapered portion with an outer surface, internal flow passage in the tapered portion, and at least one circumferential groove having a first edge and a second edge having with a sliding angle on the outer surface of the tapered portion fluidicly coupled to the internal flow passage for receiving lubricant during radial expansion and plastic deformation of the tubular member, wherein the sliding angle is less than or equal to 10 degrees. In an exemplary embodiment, the system includes a lubricant between the tubular member and the expansion device, comprising at least nine components selected from the group consisting of: a base oil; metal deactivator; antioxidants; sulfurized natural oils; phosphate ester; phosphoric acid; viscosity modifier; pour-point depressant; defoamer; and carboxylic acid soaps. In an exemplary embodiment, the expansion device includes, a tapered portion having a tapered faceted polygonal outer expansion surface. In an exemplary embodiment, the tubular member has a non-uniform wall thickness and the expansion device includes a tapered portion having a tapered faceted polygonal outer expansion surface. In an exemplary embodiment, the expansion device includes a wellbore casing, a pipeline, or a structural support. In an exemplary embodiment, the expansion device includes expansion cone.

[00654] A method for lubricating an interface between a first element and a second element has been described that includes vaporizing a lubricant proximate to the interface to inject the lubricant in the interface. In an exemplary embodiment, the first element includes an expansion device and the second element includes tubular member during radial expansion and plastic deformation of the tubular member. In an exemplary embodiment, the method includes housing a lubricant in a reservoir having an exit passageway and

generating an electric pulse in the reservoir, thereby vaporizing the lubricant and causing a pressure pulse to force lubricant out of the exit passageway. In an exemplary embodiment, the electric pulse is generated by discharging a capacitor through electrodes stored in the lubricant. In an exemplary embodiment, the method includes housing a lubricant in a reservoir having an exit passageway; and generating a magnetic pulse in the reservoir, thereby vaporizing the lubricant and causing a pressure pulse to force lubricant out of the exit passageway. In an exemplary embodiment, the magnetic pulse is generated by current running current through magnetic coils stored in the lubricant. In an exemplary embodiment, the method includes positioning an expansion device having a first tapered end and a second end at least partially within the tubular member, displacing the expansion device relative to the tubular member to radially expand and plastically deform the tubular member; and wherein the coefficient of friction between the expansion device and the tubular member during radial expansion and plastic deformation is less than 0.08. In an exemplary embodiment, the coefficient of friction is in the range of .02 to 0.05. In an exemplary embodiment, the method includes injecting lubricant between the tubular member and the expansion device. In an exemplary embodiment, the lubricant includes oil based lubricants, H1 oil, H2 oil, H3 oil, H4 oil, H5 oil, H6 oil, H7 oil, grease, water based lubricants, drilling mud, drilling mud and solid lubricants, grease combined with a solid lubricant, at least 10% Graphite, or at least 10% Molybdenum Disulfide. In an exemplary embodiment, the method includes applying a coating on the expansion device prior to positioning within the tubular member. In an exemplary embodiment, the coating may be Phygen film. In an exemplary embodiment, the method includes applying a coating on the tubular member prior to positioning the expansion device within the tubular member. In an exemplary embodiment, the coating on the tubular member includes PTFE, PTFE based or graphite based. In an exemplary embodiment, the expansion device includes DC53 material, DC2 material, DC3 material, DC5 material, DC7 material, M2 material, CPM M4 material, 10V material, 3V material. In an exemplary embodiment, the expansion device includes an REM finish, a processed finish, or a relatively smooth surface roughness. In an exemplary embodiment, the expansion device includes a relatively smooth surface roughness and includes relatively evenly space oil pockets. In an exemplary embodiment, the expansion device includes a smooth surface roughness in the range of 0.02 to 0.1 micrometers In an exemplary embodiment, the method includes injecting lubricant through at least a portion of the expansion device between the tubular member and the expansion device. In an exemplary embodiment, the method includes injecting lubricant through at least a portion of the expansion device between the tubular member and the expansion device when a predetermined pressure is met. In an exemplary embodiment, the method includes injecting lubricant through at least two portions of the expansion device between the tubular member

and the expansion device at two different pressures. In an exemplary embodiment, the expansion device includes a tapered portion with an outer surface, internal flow passage in the tapered portion and at least one circumferential groove having a first edge and a second edge having with a sliding angle on the outer surface of the tapered portion fluidicly coupled to the internal flow passage for receiving lubricant during radial expansion and plastic deformation of the tubular member, wherein the sliding angle is less than or equal to 30 degrees. In an exemplary embodiment, the expansion device includes a tapered portion with an outer surface, internal flow passage in the tapered portion, and at least one circumferential groove having a first edge and a second edge having with a sliding angle on the outer surface of the tapered portion fluidicly coupled to the internal flow passage for receiving lubricant during radial expansion and plastic deformation of the tubular member, wherein the sliding angle is less than or equal to 10 degrees. In an exemplary embodiment, the method includes injecting lubricant between the tubular member and the expansion device, comprising at least nine components selected from the group consisting of: a base oil; metal deactivator; antioxidants; sulfurized natural oils; phosphate ester; phosphoric acid; viscosity modifier; pour-point depressant; defoamer; and carboxylic acid soaps. In an exemplary embodiment, the expansion device includes a tapered portion having a tapered faceted polygonal outer expansion surface. In an exemplary embodiment, the expansion device includes, a tapered portion having a tapered faceted polygonal outer expansion surface. In an exemplary embodiment, the tubular member has a non-uniform wall thickness and the expansion device includes a tapered portion having a tapered faceted polygonal outer expansion surface. In an exemplary embodiment, the expansion device includes a wellbore casing, a pipeline, or a structural support. In an exemplary embodiment, the expansion device includes expansion cone.

[00655] A system for lubricating an interface between a first element and a second element has been described that includes means for vaporizing a lubricant proximate to the interface to inject the lubricant in the interface. In an exemplary embodiment, the area includes an interface between an expansion device and a tubular member during radial expansion and plastic deformation of the tubular member. In an exemplary embodiment, the means for vaporizing includes a means for housing a lubricant in a reservoir having an exit passageway and a means for generating an electric pulse in the reservoir, thereby vaporizing the lubricant and causing a pressure pulse to force lubricant out of the exit passageway. In an exemplary embodiment, the electric pulse is generated by discharging a capacitor through electrodes stored in the lubricant. In an exemplary embodiment, the means for vaporizing includes means for housing a lubricant in a reservoir having an exit passageway, and means for generating a magnetic pulse in the reservoir, thereby vaporizing the lubricant and causing a pressure pulse to force lubricant out of the exit passageway. In

an exemplary embodiment, the magnetic pulse is generated by current running current through magnetic coils stored in the lubricant. In an exemplary embodiment, the system includes means for positioning an expansion device having a first tapered end and a second end at least partially within a tubular member, means for displacing the expansion device relative to the tubular member to radially expand and plastically deform the tubular member, and wherein the coefficient of friction between the expansion device and the tubular member during radial expansion and plastic deformation is less than 0.08. In an exemplary embodiment, the coefficient of friction is in the range of .02 to 0.05. In an exemplary embodiment, the system, includes a means for injecting lubricant between the tubular member and the expansion device. In an exemplary embodiment, the lubricant includes oil based lubricants, H1 oil, H2 oil, H3 oil, H4 oil, H5 oil, H6 oil, H7 oil, grease, water based lubricants, drilling mud, drilling mud and solid lubricants, grease combined with a solid lubricant, at least 10% Graphite, or at least 10% Molybdenum Disulfide. In an exemplary embodiment, the system includes a means for applying a coating on the expansion device prior to positioning within the tubular member. In an exemplary embodiment, the coating may be Phygen film. In an exemplary embodiment, the method includes applying a coating on the tubular member prior to positioning the expansion device within the tubular member. In an exemplary embodiment, the coating on the tubular member includes PTFE, PTFE based or graphite based. In an exemplary embodiment, the expansion device includes DC53 material, DC2 material, DC3 material, DC5 material, DC7 material, M2 material, CPM M4 material, 10V material, 3V material. In an exemplary embodiment, the expansion device includes an REM finish, a processed finish, or a relatively smooth surface roughness. In an exemplary embodiment, the expansion device includes a relatively smooth surface roughness and includes relatively evenly space oil pockets. In an exemplary embodiment, the expansion device includes a smooth surface roughness in the range of 0.02 to 0.1 micrometers In an exemplary embodiment, the system includes a means for injecting lubricant through at least a portion of the expansion device between the tubular member and the expansion device. In an exemplary embodiment, the system includes a means for injecting lubricant through at least a portion of the expansion device between the tubular member and the expansion device when a predetermined pressure is met. In an exemplary embodiment, the system includes a means for injecting lubricant through at least two portions of the expansion device between the tubular member and the expansion device at two different pressures. In an exemplary embodiment, the expansion device includes a tapered portion with an outer surface, internal flow passage in the tapered portion and at least one circumferential groove having a first edge and a second edge having with a sliding angle on the outer surface of the tapered portion fluidicly coupled to the internal flow passage for receiving lubricant during radial expansion and plastic deformation of the tubular

member, wherein the sliding angle is less than or equal to 30 degrees. In an exemplary embodiment, the expansion device includes a tapered portion with an outer surface, internal flow passage in the tapered portion, and at least one circumferential groove having a first edge and a second edge having with a sliding angle on the outer surface of the tapered portion fluidicly coupled to the internal flow passage for receiving lubricant during radial expansion and plastic deformation of the tubular member, wherein the sliding angle is less than or equal to 10 degrees. In an exemplary embodiment, the system includes a means for injecting lubricant between the tubular member and the expansion device, comprising at least nine components selected from the group consisting of: a base oil; metal deactivator; antioxidants; sulfurized natural oils; phosphate ester; phosphoric acid; viscosity modifier; pour-point depressant; defoamer; and carboxylic acid soaps. In an exemplary embodiment, the expansion device includes a tapered portion having a tapered faceted polygonal outer expansion surface. In an exemplary embodiment, the expansion device includes, a tapered portion having a tapered faceted polygonal outer expansion surface. In an exemplary embodiment, the tubular member has a non-uniform wall thickness and the expansion device includes a tapered portion having a tapered faceted polygonal outer expansion surface. In an exemplary embodiment, the expansion device includes a wellbore casing, a pipeline, or a structural support. In an exemplary embodiment, the expansion device includes expansion cone.

[00656] A system for radially expanding and plastically deforming a tubular member has been described that includes an expansion device positioned in the tubular member, and wherein the coefficient of friction between the expansion device and the tubular member during radial expansion and plastic deformation is less than 0.08 and wherein lubricant is stored in a reservoir with a magnetic coil in the expansion device and is injected through at least a portion of the expansion device between the tubular member and the expansion device when current runs through the magnetic coil.

[00657] A system for radially expanding and plastically deforming a tubular member has been described that includes an expansion device positioned in the tubular member, and wherein the coefficient of friction between the expansion device and the tubular member during radial expansion and plastic deformation is less than 0.08 and wherein lubricant is stored in a reservoir and injected through at least a portion of the expansion device between the tubular member and the expansion device when vaporized.

[00658] A method of radially expanding and plastically deforming a tubular member has been described that includes positioning an expansion device having a first tapered end and a second end at least partially within the tubular member, displacing the expansion device relative to the tubular member to radially expand and plastically deform the tubular member, and injecting a lubricant stored in a reservoir with a magnetic coil in the expansion

device through at least a portion of the expansion device between the tubular member and the expansion device when current runs through the magnetic coil, and wherein the coefficient of friction between the expansion device and the tubular member during radial expansion and plastic deformation is less than 0.08.

[00659] A method of radially expanding and plastically deforming a tubular member has been described that includes positioning an expansion device having a first tapered end and a second end at least partially within the tubular member, displacing the expansion device relative to the tubular member to radially expand and plastically deform the tubular member, and vaporizing a lubricant stored in a reservoir in the expansion device and injecting it through at least a portion of the expansion device between the tubular member and the expansion device, and wherein the coefficient of friction between the expansion device and the tubular member during radial expansion and plastic deformation is less than 0.08.

[00660] A system for radially expanding and plastically deforming a tubular member has been described that includes means for positioning an expansion device having a first tapered end and a second end at least partially within the tubular member, means for displacing the expansion device relative to the tubular member to radially expand and plastically deform the tubular member, and wherein the coefficient of friction between the expansion device and the tubular member during radial expansion and plastic deformation is less than 0.08 and wherein lubricant is stored in a reservoir and injected through at least a portion of the expansion device between the tubular member and the expansion device when vaporized.

[00661] A system for radially expanding and plastically deforming a tubular member has been described that includes means for positioning an expansion device having a first tapered end and a second end at least partially within the tubular member, means for displacing the expansion device relative to the tubular member to radially expand and plastically deform the tubular member; and wherein the coefficient of friction between the expansion device and the tubular member during radial expansion and plastic deformation is less than 0.08 and wherein lubricant is stored in a reservoir with a magnetic coil in the expansion device and is injected through at least a portion of the expansion device between the tubular member and the expansion device when current runs through the magnetic coil.

[00662] A system for radially expanding and plastically deforming a tubular member has been described that includes means for positioning an expansion device having a first tapered end and a second end at least partially within the tubular member, means for displacing the expansion device relative to the tubular member to radially expand and plastically deform the tubular member, and means for vaporizing lubricant stored in a reservoir and injecting it through at least a portion of the expansion device between the

tubular member and the expansion device, wherein the coefficient of friction between the expansion device and the tubular member during radial expansion and plastic deformation is less than 0.08.

[00663] A system for radially expanding and plastically deforming a tubular member has been described that includes means for positioning an expansion device having a first tapered end and a second end at least partially within the tubular member, means for displacing the expansion device relative to the tubular member to radially expand and plastically deform the tubular member, and means for vaporizing lubricant stored in a reservoir and injecting it through at least a portion of the expansion device between the tubular member and the expansion device, wherein the coefficient of friction between the expansion device and the tubular member during radial expansion and plastic deformation is less than 0.08 and wherein means for vaporizes comprises a magnetic coil in the reservoir operably connected to a power source.

[00664] An expansion device for radially expanding and plastically deforming the tubular member has been described that includes one or more expansion surfaces on the expansion device for engaging the interior surface of the tubular member during the radial expansion and plastic deformation of the tubular member; and a lubrication device operably coupled to the expansion surface for injecting lubricant into an interface between the expansion surface and the tubular member during the radial expansion and plastic deformation of the tubular member when a predetermined lubricant pressure is reached, wherein lubricant is stored in a reservoir in the lubrication device and injected through at least a portion of the expansion device between the tubular member and the expansion device when vaporized.

[00665] An expansion device for radially expanding and plastically deforming the tubular member has been described that includes one or more expansion surfaces on the expansion device for engaging the interior surface of the tubular member during the radial expansion and plastic deformation of the tubular member, and a lubrication device operably coupled to the expansion surface for injecting lubricant into an interface between the expansion surface and the tubular member during the radial expansion and plastic deformation of the tubular member when a predetermined lubricant pressure is reached, and wherein lubricant is stored in a reservoir with a magnetic coil in the expansion device and is injected through at least a portion of the expansion device between the tubular member and the expansion device when current runs through the magnetic coil.

[00666] A method for radially expanding and plastically deforming the tubular member has been described that includes positioning an expansion device having one or more expansion surfaces in the interior surface of the tubular member, displacing the expansion device relative to the tubular member to radially expand and plastically deform the tubular

member, operating a lubrication device to inject lubricant into an interface between the expansion surface and the tubular member when a predetermined lubricant pressure is reached, and wherein lubricant is stored in a reservoir in the lubrication device and injected through at least a portion of the expansion device between the tubular member and the expansion device when vaporized.

[00667] A method for radially expanding and plastically deforming the tubular member has been described that includes positioning an expansion device having one or more expansion surfaces in the interior surface of the tubular member; displacing the expansion device relative to the tubular member to radially expand and plastically deform the tubular member, operating a lubrication device to inject lubricant into an interface between the expansion surface and the tubular member when a predetermined lubricant pressure is reached, and wherein lubricant is stored in a reservoir with a magnetic coil in the expansion device and is injected through at least a portion of the expansion device between the tubular member and the expansion device when current runs through the magnetic coil.

[00668] A lubricant delivery assembly for radially expanding and plastically deforming a tubular member has been described that includes an expansion cone having a tapered portion with an outer surface, at least one reservoir for housing a lubricant, at least one circumferential groove on the outer surface fluidicly connected to the reservoir and a lubricant injection mechanism to force lubricant into the at least one circumferential groove while radially expanding and plastically deforming the tubular member when a predetermined lubricant pressure is reached. In an exemplary embodiment, the lubricant is stored in a reservoir with a magnetic coil in the expansion device and is injected through at least a portion of the expansion device between the tubular member and the expansion device when current runs through the magnetic coil. In an exemplary embodiment, the lubricant is stored in a reservoir in the lubrication device and injected through at least a portion of the expansion device between the tubular member and the expansion device when vaporized. In an exemplary embodiment, the lubricant is stored in a reservoir with electrodes that are electrically coupled a capacitor in the expansion device and is injected through at least a portion of the expansion device between the tubular member and the expansion device when the capacitors discharges.

[00669] An expansion device for radially expanding and plastically deforming a tubular member has been described that includes a tapered portion with an outer surface, internal flow passage in the tapered portion, and at least one circumferential groove having a first edge and a second edge with a predetermined sliding angle on the outer surface of the tapered portion fluidicly coupled to the internal flow passage for receiving lubricant during radial expansion and plastic deformation of the tubular member, wherein the sliding angle is less than or equal to 30 degrees. In an exemplary embodiment, the lubricant is stored in a

reservoir with a magnetic coil in the expansion device and is injected through at least a portion of the expansion device between the tubular member and the expansion device when current runs through the magnetic coil. In an exemplary embodiment, the lubricant is stored in a reservoir in the lubrication device and injected through at least a portion of the expansion device between the tubular member and the expansion device when vaporized. In an exemplary embodiment, the lubricant is stored in a reservoir with electrodes that are electrically coupled a capacitor in the expansion device and is injected through at least a portion of the expansion device between the tubular member and the expansion device when the capacitors discharges.

[00670] An expansion cone for radially expanding and plastically deforming a tubular member has been described that includes a leading portion with an outer surface, internal flow passage in the leading portion, at least one circumferential groove on the outer surface of the tapered portion fluidicly coupled to the internal flow passage for receiving lubricant during radial expansion and plastic deformation of the tubular member, a tapered portion with an outer surface, internal flow passage in the tapered portion and at least one circumferential groove on the outer surface of the tapered portion fluidicly coupled to the internal flow passage for receiving lubricant during radial expansion and plastic deformation of the tubular member. In an exemplary embodiment, the lubricant is stored in a reservoir with a magnetic coil in the expansion device and is injected through at least a portion of the expansion device between the tubular member and the expansion device when current runs through the magnetic coil. In an exemplary embodiment, the lubricant is stored in a reservoir in the lubrication device and injected through at least a portion of the expansion device between the tubular member and the expansion device when vaporized. In an exemplary embodiment, the lubricant is stored in a reservoir with electrodes that are electrically coupled a capacitor in the expansion device and is injected through at least a portion of the expansion device between the tubular member and the expansion device when the capacitors discharges.

[00671] An expansion cone for radially expanding and plastically deforming a tubular member has been described that includes a leading portion with an outer surface, internal flow passage in the leading portion, at least one circumferential groove on the outer surface of the tapered portion fluidicly coupled to the internal flow passage for receiving lubricant during radial expansion and plastic deformation of the tubular member, a tapered portion with an outer surface, internal flow passage in the tapered portion, at least one circumferential groove on the outer surface of the tapered portion fluidicly coupled to the internal flow passage for receiving lubricant during radial expansion and plastic deformation of the tubular member, wherein the lubricant in the leading portion is at pressure different from the lubricant in the tapered portion. In an exemplary embodiment, the lubricant is

stored in a reservoir with a magnetic coil in the expansion device and is injected through at least a portion of the expansion device between the tubular member and the expansion device when current runs through the magnetic coil. In an exemplary embodiment, the lubricant is stored in a reservoir in the lubrication device and injected through at least a portion of the expansion device between the tubular member and the expansion device when vaporized. In an exemplary embodiment, the lubricant is stored in a reservoir with electrodes that are electrically coupled a capacitor in the expansion device and is injected through at least a portion of the expansion device between the tubular member and the expansion device when the capacitors discharges.

[00672] An expansion cone for radially expanding and plastically deforming a tubular member has been described that includes a leading portion with an outer surface, internal flow passage in the leading portion, at least one circumferential groove on the outer surface of the tapered portion fluidicly coupled to the internal flow passage for receiving lubricant during radial expansion and plastic deformation of the tubular member, a tapered portion with an outer surface, internal flow passage in the tapered portion, at least one circumferential groove having a first edge and a second edge with a second predetermined sliding angle on the outer surface of the tapered portion fluidicly coupled to the internal flow passage for receiving lubricant during radial expansion and plastic deformation of the tubular member; wherein the second sliding angle is less than or equal to 30 degrees. In an exemplary embodiment, the lubricant is stored in a reservoir with a magnetic coil in the expansion device and is injected through at least a portion of the expansion device between the tubular member and the expansion device when current runs through the magnetic coil. In an exemplary embodiment, the lubricant is stored in a reservoir in the lubrication device and injected through at least a portion of the expansion device between the tubular member and the expansion device when vaporized. In an exemplary embodiment, the lubricant is stored in a reservoir with electrodes that are electrically coupled a capacitor in the expansion device and is injected through at least a portion of the expansion device between the tubular member and the expansion device when the capacitors discharges.

[00673] An expansion cone for radially expanding and plastically deforming a tubular member has been described that includes a leading portion with an outer surface internal flow passage in the leading portion, at least one circumferential groove on the outer surface of the tapered portion fluidicly coupled to the internal flow passage for receiving lubricant during radial expansion and plastic deformation of the tubular member, a tapered portion with an outer surface, internal flow passage in the tapered portion, at least one circumferential groove having a first edge and a second edge with a second predetermined sliding angle on the outer surface of the tapered portion fluidicly coupled to the internal flow passage for receiving lubricant during radial expansion and plastic deformation of the tubular

member; wherein the second sliding angle is less than or equal to 30 degrees. In an exemplary embodiment, the lubricant is stored in a reservoir with a magnetic coil in the expansion device and is injected through at least a portion of the expansion device between the tubular member and the expansion device when current runs through the magnetic coil. In an exemplary embodiment, the lubricant is stored in a reservoir in the lubrication device and injected through at least a portion of the expansion device between the tubular member and the expansion device when vaporized. In an exemplary embodiment, the lubricant is stored in a reservoir with electrodes that are electrically coupled a capacitor in the expansion device and is injected through at least a portion of the expansion device between the tubular member and the expansion device when the capacitors discharges.

[00674] An expansion cone for radially expanding and plastically deforming a tubular member has been described that includes a leading portion with an outer surface, internal flow passage in the leading portion, at least one circumferential groove on the outer surface of the tapered portion fluidicly coupled to the internal flow passage for receiving lubricant during radial expansion and plastic deformation of the tubular member from the internal flow passage, a tapered portion with an outer surface, internal flow passage in the tapered portion, at least one circumferential groove having a first edge and a second edge with a second predetermined sliding angle on the outer surface of the tapered portion fluidicly coupled to the internal flow passage for receiving lubricant during radial expansion and plastic deformation of the tubular member; wherein the second sliding angle is less than or equal to 30 degrees, wherein the lubricant in the leading portion is at pressure different from the lubricant in the tapered portion. In an exemplary embodiment, the lubricant is stored in a reservoir with a magnetic coil in the expansion device and is injected through at least a portion of the expansion device between the tubular member and the expansion device when current runs through the magnetic coil. In an exemplary embodiment, the lubricant is stored in a reservoir in the lubrication device and injected through at least a portion of the expansion device between the tubular member and the expansion device when vaporized. In an exemplary embodiment, the lubricant is stored in a reservoir with electrodes that are electrically coupled a capacitor in the expansion device and is injected through at least a portion of the expansion device between the tubular member and the expansion device when the capacitors discharges.

[00675] A method of reducing the coefficient of friction between the expansion device and the tubular member during radial expansion to less than 0.08 has been described that includes altering at least one of the elements selected from the group consisting of: expansion device geometry, expansion device composition, expansion device surface roughness, expansion device texture, expansion device coating, lubricant composition, lubricant environmental issues, lubricant frictional modifiers, tubular member roughness, and

tubular member coating. In an exemplary embodiment, the lubricant is stored in a reservoir with a magnetic coil in the expansion device and is injected through at least a portion of the expansion device between the tubular member and the expansion device when current runs through the magnetic coil. In an exemplary embodiment, the lubricant is stored in a reservoir in the lubrication device and injected through at least a portion of the expansion device between the tubular member and the expansion device when vaporized. In an exemplary embodiment, the lubricant is stored in a reservoir with electrodes that are electrically coupled a capacitor in the expansion device and is injected through at least a portion of the expansion device between the tubular member and the expansion device when the capacitors discharges.

[00676] A system for radially expanding and plastically deforming a tubular member having a non-uniform wall thickness has been disclosed that includes an expansion device having one or more expansion surfaces and a tapered portion having a tapered faceted polygonal outer expansion surface in the interior surface of the tubular member. In an alternate embodiment, the system includes lubricant between the tubular member and the expansion device. In an exemplary embodiment, the lubricant includes oil based lubricants, H1 oil, H2 oil, H3 oil, H4 oil, H5 oil, H6 oil, H7 oil, grease, water based lubricants, drilling mud, drilling mud and solid lubricants, grease combined with a solid lubricant, at least 10% Graphite, or at least 10% Molybdenum Disulfide. In an exemplary embodiment, the system includes a coating on the expansion device. In an exemplary embodiment, the coating may be Phygen film. In an exemplary embodiment, the system includes a coating on the tubular member. In an exemplary embodiment, the coating on the tubular member includes PTFE, PTFE based or graphite based. In an exemplary embodiment, the expansion device includes DC53 material, DC2 material, DC3 material, DC5 material, DC7 material, M2 material, CPM M4 material, 10V material, 3V material. In an exemplary embodiment, the expansion device includes an REM finish, a processed finish, or a relatively smooth surface roughness. In an exemplary embodiment, the expansion device includes a relatively smooth surface roughness and includes relatively evenly space oil pockets. In an exemplary embodiment, the expansion device includes a smooth surface roughness in the range of 0.02 to 0.1 micrometers In an exemplary embodiment, the lubricant is injected through at least a portion of the expansion device between the tubular member and the expansion device. In an exemplary embodiment, the lubricant is injected through at least a portion of the expansion device between the tubular member and the expansion device when a predetermined pressure is met. In an exemplary embodiment, the lubricant is injected through at least two portions of the expansion device between the tubular member and the expansion device at two different pressures. In an exemplary embodiment, the expansion device includes a tapered portion with an outer surface, internal flow passage in the tapered portion and at

least one circumferential groove having a first edge and a second edge having with a sliding angle on the outer surface of the tapered portion fluidicly coupled to the internal flow passage for receiving lubricant during radial expansion and plastic deformation of the tubular member, wherein the sliding angle is less than or equal to 30 degrees. In an exemplary embodiment, the expansion device includes a tapered portion with an outer surface, internal flow passage in the tapered portion, and at least one circumferential groove having a first edge and a second edge having with a sliding angle on the outer surface of the tapered portion fluidicly coupled to the internal flow passage for receiving lubricant during radial expansion and plastic deformation of the tubular member, wherein the sliding angle is less than or equal to 10 degrees. In an exemplary embodiment, the system includes a lubricant between the tubular member and the expansion device, comprising at least nine components selected from the group consisting of: a base oil; metal deactivator; antioxidants; sulfurized natural oils; phosphate ester; phosphoric acid; viscosity modifier; pour-point depressant; defoamer; and carboxylic acid soaps. In an exemplary embodiment, the lubricant is stored in a reservoir with electrodes that are electrically coupled a capacitor in the expansion device and is injected through at least a portion of the expansion device between the tubular member and the expansion device when the capacitors discharges. In an exemplary embodiment, the expansion device includes a wellbore casing, a pipeline, or a structural support. In an exemplary embodiment, the expansion device includes expansion cone.

[00677] A method of radially expanding and plastically deforming a tubular member having a non-uniform wall thickness has been described that includes positioning an expansion device having one or more expansion surfaces and a tapered portion having a tapered faceted polygonal outer expansion surface in the interior surface of the tubular member, and displacing the expansion device relative to the tubular member to radially expand and plastically deform the tubular member. In an exemplary embodiment, the method includes injecting lubricant between the tubular member and the expansion device. In an exemplary embodiment, the lubricant includes oil based lubricants, H1 oil, H2 oil, H3 oil, H4 oil, H5 oil, H6 oil, H7 oil, grease, water based lubricants, drilling mud, drilling mud and solid lubricants, grease combined with a solid lubricant, at least 10% Graphite, or at least 10% Molybdenum Disulfide. In an exemplary embodiment, the method includes applying a coating on the expansion device prior to positioning within the tubular member. In an exemplary embodiment, the coating may be Phygen film. In an exemplary embodiment, the method includes applying a coating on the tubular member prior to positioning the expansion device within the tubular member. In an exemplary embodiment, the coating on the tubular member includes PTFE, PTFE based or graphite based. In an exemplary embodiment, the expansion device includes DC53 material, DC2 material, DC3 material, DC5 material, DC7

material, M2 material, CPM M4 material, 10V material, 3V material. In an exemplary embodiment, the expansion device includes an REM finish, a processed finish, or a relatively smooth surface roughness. In an exemplary embodiment, the expansion device includes a relatively smooth surface roughness and includes relatively evenly space oil pockets. In an exemplary embodiment, the expansion device includes a smooth surface roughness in the range of 0.02 to 0.1 micrometers In an exemplary embodiment, the method includes injecting lubricant through at least a portion of the expansion device between the tubular member and the expansion device. In an exemplary embodiment, the method includes injecting lubricant through at least a portion of the expansion device between the tubular member and the expansion device when a predetermined pressure is met. In an exemplary embodiment, the method includes injecting lubricant through at least two portions of the expansion device between the tubular member and the expansion device at two different pressures. In an exemplary embodiment, the expansion device includes a tapered portion with an outer surface, internal flow passage in the tapered portion and at least one circumferential groove having a first edge and a second edge having with a sliding angle on the outer surface of the tapered portion fluidicly coupled to the internal flow passage for receiving lubricant during radial expansion and plastic deformation of the tubular member, wherein the sliding angle is less than or equal to 30 degrees. In an exemplary embodiment, the expansion device includes a tapered portion with an outer surface, internal flow passage in the tapered portion, and at least one circumferential groove having a first edge and a second edge having with a sliding angle on the outer surface of the tapered portion fluidicly coupled to the internal flow passage for receiving lubricant during radial expansion and plastic deformation of the tubular member, wherein the sliding angle is less than or equal to 10 degrees. In an exemplary embodiment, the method includes injecting lubricant between the tubular member and the expansion device, comprising at least nine components selected from the group consisting of: a base oil; metal deactivator; antioxidants; sulfurized natural oils; phosphate ester; phosphoric acid; viscosity modifier; pour-point depressant; defoamer; and carboxylic acid soaps. In an exemplary embodiment, the lubricant is stored in a reservoir with electrodes that are electrically coupled a capacitor in the expansion device and is injected through at least a portion of the expansion device between the tubular member and the expansion device when the capacitors discharges. In an exemplary embodiment, the expansion device includes a wellbore casing, a pipeline, or a structural support. In an exemplary embodiment, the expansion device includes expansion cone.

[00678] An expansion device for radially expanding and plastically deforming a tubular member has been described that includes a tapered portion with an outer surface, internal flow passage in the tapered portion, and at least one circumferential groove having a first edge and a second edge with a predetermined sliding angle on the outer surface of the

tapered portion fluidicly coupled to the internal flow passage for receiving lubricant during radial expansion and plastic deformation of the tubular member, wherein the sliding angle is less than or equal to 30 degrees; and wherein lubricant is stored in a reservoir with electrodes that are electrically coupled a capacitor in the expansion device and is injected through at least a portion of the expansion device between the tubular member and the expansion device when the capacitors discharges.

[00679] An expansion cone for radially expanding and plastically deforming a tubular member has been described that includes a leading portion with an outer surface, internal flow passage in the leading portion, at least one circumferential groove on the outer surface of the tapered portion fluidicly coupled to the internal flow passage for receiving lubricant during radial expansion and plastic deformation of the tubular member, a tapered portion with an outer surface; internal flow passage in the tapered portion; and at least one circumferential groove on the outer surface of the tapered portion fluidicly coupled to the internal flow passage for receiving lubricant during radial expansion and plastic deformation of the tubular member, wherein lubricant is stored in a reservoir with electrodes that are electrically coupled a capacitor in the expansion device and is injected through at least a portion of the expansion device between the tubular member and the expansion device when the capacitors discharges.

[00680] An expansion cone for radially expanding and plastically deforming a tubular member has been described that includes a leading portion with an outer surface, internal flow passage in the leading portion, at least one circumferential groove on the outer surface of the tapered portion fluidicly coupled to the internal flow passage for receiving lubricant during radial expansion and plastic deformation of the tubular member, a tapered portion with an outer surface, internal flow passage in the tapered portion; and at least one circumferential groove on the outer surface of the tapered portion fluidicly coupled to the internal flow passage for receiving lubricant during radial expansion and plastic deformation of the tubular member, wherein the lubricant in the leading portion is at pressure different from the lubricant in the tapered portion, and wherein lubricant is stored in a reservoir with electrodes that are electrically coupled a capacitor in the expansion device and is injected through at least a portion of the expansion device between the tubular member and the expansion device when the capacitors discharges.

[00681] An expansion cone for radially expanding and plastically deforming a tubular member has been described that includes a leading portion with an outer surface, internal flow passage in the leading portion, at least one circumferential groove on the outer surface of the tapered portion fluidicly coupled to the internal flow passage for receiving lubricant during radial expansion and plastic deformation of the tubular member, a tapered portion with an outer surface, internal flow passage in the tapered portion, and at least one

circumferential groove having a first edge and a second edge with a second predetermined sliding angle on the outer surface of the tapered portion fluidicly coupled to the internal flow passage for receiving lubricant during radial expansion and plastic deformation of the tubular member; wherein the second sliding angle is less than or equal to 30 degrees, wherein lubricant is stored in a reservoir with electrodes that are electrically coupled a capacitor in the expansion device and is injected through at least a portion of the expansion device between the tubular member and the expansion device when the capacitors discharges.

[00682] An expansion cone for radially expanding and plastically deforming a tubular member has been described that includes a leading portion with an outer surface, internal flow passage in the leading portion, at least one circumferential groove on the outer surface of the tapered portion fluidicly coupled to the internal flow passage for receiving lubricant during radial expansion and plastic deformation of the tubular member, a tapered portion with an outer surface, internal flow passage in the tapered portion; and at least one circumferential groove having a first edge and a second edge with a second predetermined sliding angle on the outer surface of the tapered portion fluidicly coupled to the internal flow passage for receiving lubricant during radial expansion and plastic deformation of the tubular member; wherein the second sliding angle is less than or equal to 30 degrees., wherein lubricant is stored in a reservoir with electrodes that are electrically coupled a capacitor in the expansion device and is injected through at least a portion of the expansion device between the tubular member and the expansion device when the capacitors discharges.

[00683] An expansion cone for radially expanding and plastically deforming a tubular member has been described that includes a leading portion with an outer surface, internal flow passage in the leading portion, at least one circumferential groove on the outer surface of the tapered portion fluidicly coupled to the internal flow passage for receiving lubricant during radial expansion and plastic deformation of the tubular member from the internal flow passage. a tapered portion with an outer surface, internal flow passage in the tapered portion; and at least one circumferential groove having a first edge and a second edge with a second predetermined sliding angle on the outer surface of the tapered portion fluidicly coupled to the internal flow passage for receiving lubricant during radial expansion and plastic deformation of the tubular member; wherein the second sliding angle is less than or equal to 30 degrees, wherein the lubricant in the leading portion is at pressure different from the lubricant in the tapered portion, and wherein lubricant is stored in a reservoir with electrodes that are electrically coupled a capacitor in the expansion device and is injected through at least a portion of the expansion device between the tubular member and the expansion device when the capacitors discharges.

[00684] A system for radially expanding and plastically deforming a tubular member having non-uniform wall thickness has been described that includes means for positioning

an expansion device having one or more expansion surfaces and a tapered portion having a tapered faceted polygonal outer expansion surface in the interior surface of the tubular member; and means for displacing the expansion device relative to the tubular member to radially expand and plastically deform the tubular member.

[00685] A system for radially expanding and plastically deforming a tubular member has been described that includes an expansion cone of D53 material having a phygen coating and an REM finish and H1 oil wherein the tubular member is coated with PTFE.

[00686] A method of increasing a collapse strength of a tubular member after a radial expansion and plastic deformation of the tubular member using an expansion device has been described that includes reducing a coefficient of friction between the tubular member and the expansion device during the radial expansion and plastic deformation of the tubular member; and reducing a ratio of a diameter of the tubular member to a wall thickness of the tubular member. In an exemplary embodiment, the coefficient of friction is less than 0.075. In an exemplary embodiment, the ratio of the diameter of the tubular member to a wall thickness of the tubular member is less than 21.6. In an exemplary embodiment, the collapse strength of a tubular member after the radial expansion and plastic deformation of the tubular member using an expansion device is greater than 5000 ksi.

[00687] A system for radially expanding and plastically deforming a tubular member has been described that includes a tubular member, and an expansion device positioned within the tubular member, wherein the coefficient of friction between the tubular member and the expansion device is less than 0.075, and wherein the ratio of the diameter of the tubular member to a wall thickness of the tubular member is less than 21.6.

[00688] A method of radially expanding and plastically deforming a tubular member using an expansion device has been described that includes quenching and tempering the tubular member; positioning the tubular member within a preexisting structure; and radially expanding and plastically deforming the tubular member. In an exemplary embodiment, the yield strength of the tubular member ranges from about 76.8 ksi to 88.8 ksi. In an exemplary embodiment, the ratio of the yield strength to the tensile strength of the tubular member ranges from about 0.82 to 0.86. In an exemplary embodiment, the longitudinal elongation of the tubular member prior to failure ranges from about 14.8% to 22.0%. In an exemplary embodiment, the width reduction of the tubular member prior to failure ranges from about 32% to 44.0%. In an exemplary embodiment, the width thickness reduction of the tubular member prior to failure ranges from about 41.0% to 45%. In an exemplary embodiment, the anisotropy of the tubular member ranges from about 0.65 to 1.03. In an exemplary embodiment, the absorbed energy in the longitudinal direction of the tubular member ranges from about 125 to 145 ft-lbs. In an exemplary embodiment, the absorbed energy in the transverse direction of the tubular member ranges from about 59 to 59 ft-lbs. In an

exemplary embodiment, the absorbed energy in a welded portion of the tubular member ranges from about 174 to 176 ft-lbs. In an exemplary embodiment, a flared expansion of an end of tubular member ranged from about 42 to 52%. In an exemplary embodiment, the tubular member comprises, by weight percentage: 0.27 C; 0.14 Si; 1.28 Mn; 0.009 P; 0.005 S; and 0.14 Cr. In an exemplary embodiment, the quenching of the tubular member is provided at about 970 C; and the tempering the tubular member is provided at about 670 C.

[00689] A radially expandable and plastically deformable tubular member has been described that includes a yield strength ranging from about 76.8 ksi to 88.8 ksi, a ratio of the yield strength to a tensile strength of the tubular member ranging from about 0.82 to 0.86, a longitudinal elongation of the tubular member prior to failure ranging from about 14.8% to 22.0%, a width reduction of the tubular member prior to failure ranging from about 32% to 44.0%, a width thickness reduction of the tubular member prior to failure ranges from about 41.0% to 45%, and an anisotropy of the tubular member ranges from about 0.65 to 1.03. In an exemplary embodiment, an absorbed energy in the longitudinal direction of the tubular member ranges from about 125 to 145 ft-lbs. In an exemplary embodiment, the absorbed energy in the transverse direction of the tubular member ranges from about 59 to 59 ft-lbs. In an exemplary embodiment, the absorbed energy in a welded portion of the tubular member ranges from about 174 to 176 ft-lbs. In an exemplary embodiment, a flared expansion of an end of tubular member ranged from about 42 to 52%. In an exemplary embodiment, the tubular member comprises, by weight percentage: 0.27 C; 0.14 Si; 1.28 Mn; 0.009 P; 0.005 S; and 0.14 Cr.

[00690] A radially expandable and plastically deformable tubular member has been described that includes: a yield strength ranging from about 40.0 ksi to 100.0 ksi; a ratio of the yield strength to a tensile strength of the tubular member ranging from about 0.40 to 0.85; a longitudinal elongation of the tubular member prior to failure ranging from at least about 22.0 to 35.0%; a width reduction of the tubular member prior to failure ranging from at least about 30.0% to 45.0%; a width thickness reduction of the tubular member prior to failure ranges from at least about 30.0% to 45.0%; and an anisotropy of the tubular member ranges from at least about 0.65 to 1.50. In an exemplary embodiment, an absorbed energy in the longitudinal direction of the tubular member is at least about 80 ft-lbs. In an exemplary embodiment, the absorbed energy in the transverse direction of the tubular member is at least about 60 ft-lbs. In an exemplary embodiment, the absorbed energy in a welded portion of the tubular member is at least about 60 ft-lbs. In an exemplary embodiment, a flared expansion of an end of tubular member ranges from at least about 45 to 75%.

[00691] A method of manufacturing a tubular member has been described that includes fabricating a tubular member; positioning the tubular member within a preexisting structure; radially expanding and plastically deforming the tubular member within the

preexisting structure; and baking the tubular member within the preexisting structure. In an exemplary embodiment, the preexisting structure comprises a wellbore. In an exemplary embodiment, the fabricated tubular member comprises a dual phase steel pipe. In an exemplary embodiment, the fabricated tubular member comprises a microstructure comprising about 15 to 30% martensite; and ferrite. In an exemplary embodiment, the fabricated tubular member comprises, by weight percentage: 0.1 C; 1.2 Mn; and 0.3 Si. In an exemplary embodiment, the fabricated tubular member comprises a TRIP steel pipe. In an exemplary embodiment, fabricating the tubular member comprises: cold rolling the tubular member; and inter critical annealing the tubular member. In an exemplary embodiment, the fabricated tubular member comprises a dual phase steel pipe. In an exemplary embodiment, prior to the cold rolling, the fabricated tubular member comprises a microstructure comprising ferrite and pearlite. In an exemplary embodiment, the inter critical annealing is performed at about 750 C. In an exemplary embodiment, after the inter critical annealing, the fabricated tubular member comprises a microstructure comprising ferrite and at least one of pearlite and austentite. In an exemplary embodiment, the method further comprising: cooling the tubular member after the inter critical annealing. In an exemplary embodiment, after the cooling, the tubular member comprises a microstructure comprising martensite. In an exemplary embodiment, the baking is provided at about 100 C to 250 C. In an exemplary embodiment, following at least a portion of the baking, the tubular member comprises a bake-hardened portion. In an exemplary embodiment, following at least a portion of the baking, the tubular member comprises a stress-relieved portion. In an exemplary embodiment, following at least a portion of the baking, the tubular member comprises a bake-hardened portion and a stress-relieved portion. In an exemplary embodiment, the cold rolling comprises: allowing the tubular member to cool over time from a first temperature to a second temperature along a temperature versus time curve; and at a plurality of stages along the curve, deforming the tubular member. In an exemplary embodiment, at a first stage along the curve, insoluble precipitates within the tubular member retard austentite growth. In an exemplary embodiment, at a first stage along the curve, deformation of the tubular member promotes precipitation. In an exemplary embodiment, at a second stage along the curve, insoluble precipitates within the tubular member inhibit recrystallization. In an exemplary embodiment, at a second stage along the curve, austentite grains are conditioned.

[00692] It is understood that variations may be made in the foregoing without departing from the scope of the invention. For example, the teachings of the present illustrative embodiments may be used to provide a wellbore casing, a pipeline, or a structural support. Furthermore, the elements and teachings of the various illustrative embodiments may be combined in whole or in part in some or all of the illustrative embodiments. In

addition, one or more of the elements and teachings of the various illustrative embodiments may be omitted, at least in part, and/or combined, at least in part, with one or more of the other elements and teachings of the various illustrative embodiments.

[00693] Although illustrative embodiments of the invention have been shown and described, a wide range of modification, changes and substitution is contemplated in the foregoing disclosure. In some instances, some features of the present invention may be employed without a corresponding use of the other features. Accordingly, it is appropriate that the appended claims be construed broadly and in a manner consistent with the scope of the invention.